

# Lower Ordovician Brachiopoda from the Tourmakeady Limestone, Co. Mayo, Ireland

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## Synopsis

A study of fossil Brachiopoda collected from etched residues of the Upper Arenig Tourmakeady Limestone, Co. Mayo, Republic of Ireland, reveals the presence of 45 species (25 of them new) belonging to 41 genera of which 12 are new. The new inarticulate genera recognized are the lingulacean *Dictyobolus*, the acrotretacean *Myloconotreta* (probably two species), and the siphonotretaceans *Cyrbasiotreta* and *Karnotreta*. The 8 new articulate genera comprise the orthaceans *Protohesperonomia*, *Lomatorthis*, *Notoscaphidia* and *Crossiskenidium* (two species); the clitambonitacean *Acantho-toechia*; the plectambonitaceans *Borua* and *Tourmakeadia* and the porambonitacean *Acanthoglyphia*. The fauna additionally contains new species of *Lingulobolus*, *Lingulella*, *Conotreta*, *Ceratreta*, *Multispinula*, *Archaeorthis*, *Taphrorthis*, *Phragmorthis*, *Protoskenidioides*, *Pomatotrema*, *Leptella*, *Syntrophina* and *Porambonites*, as well as representatives of *Westonia*, *Plectoglossa* (?), *Acanthambonia*, *Elliptoglossa*, *Conotreta*, *Scaphelasma*, *Eoconulus*, *Schizotreta*, *Multispinula*, *Apheorthis*, *Orthidium*, *Nothorthis*, *Orthambonites*, *Tritoechia*, *Punctolira* (?) and *Idiostrophia*.

The Tourmakeady fauna shows strong North American affinities, with only one of the established genera not previously recorded in Upper Cambrian or Lower and Middle Ordovician successions from that continent.

## Introduction

This paper is a systematic study of the brachiopod remains recovered from the Lower Ordovician Tourmakeady Limestone and associated rocks exposed in Co. Mayo, Republic of Ireland. Although the geology of the Lower Ordovician inliers in the Tourmakeady and Glensaul districts was first described in detail by Gardiner & Reynolds (1909, 1910), the abundance of the shelly fossils was not then appreciated and the rich assemblages have never been subjected to full taxonomic investigation. Gardiner & Reynolds did, however, recognize the stratigraphical importance of the inliers, and their age determinations were based on lists of graptolitic and shelly faunas collected from various exposures within the Tourmakeady and Glensaul successions. The graptolite faunas have been reinvestigated

(Dewey *et al.* 1970), but up to now the shelly fossils have been known only from two brief palaeontological accounts by Reed (*in* Gardiner & Reynolds 1909, 1910), describing six brachiopod species.

Intensive collecting, which furnished the material for the present study, began in 1963 when it was discovered that the skeletal remains of many phyla represented in the richly fossiliferous Tourmakeady Limestone had been silicified. Bulk sampling and acid etching of over two tons of limestone revealed an early Ordovician brachiopod fauna of unprecedented diversity, much of it previously undescribed. Moreover, other phyla were well represented in the etched residues and are now being described. In due course this study will be complemented by a description of the Tourmakeady trilobites by R. A. Fortey, and by illustrations of other rarer but still important groups, notably bryozoans, gastropods and crinoids, thereby completing the taxonomy of a major fauna which is significant not only because of its abundance, preservation, and diversity, but also because of the information it provides on Lower Ordovician biogeography.

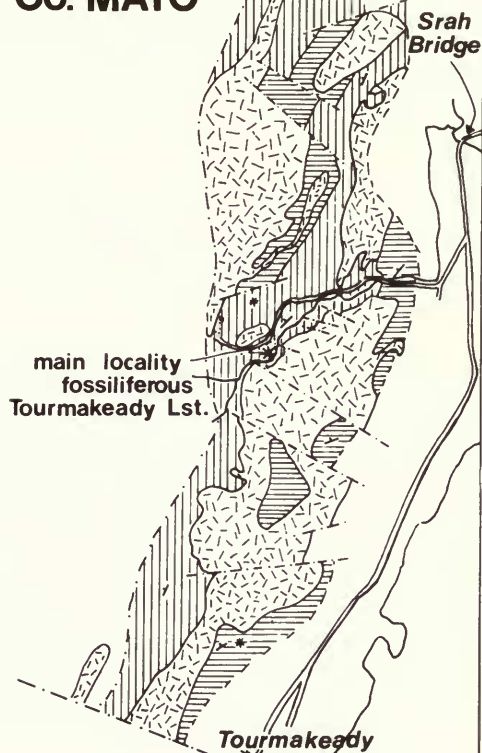
The Tourmakeady Limestone occurs in isolated blocks within well-bedded calcareous tuffs and grits. Together these lithologies constitute the 'Shangort and Tourmakeady Beds' of Gardiner & Reynolds, a term retained herein (Fig. 1) although rigorous application of stratigraphic procedure, beyond the scope of this work, would require the establishment of more precisely defined formational units. The shelly fossils indicate an Upper Arenig age for the Tourmakeady Limestone, equivalent to Zone K of the North American biostratigraphical succession (see table in Curry *et al.* 1982). This is consistent with the graptolite evidence, which includes an uppermost Lower Arenig assemblage ascribed to the *Isograptus gibberulus* Zone near the base of the Shangort and Tourmakeady Beds, and an Upper Arenig assemblage indicative of the *Didymograptus hirundo* Zone for a new locality at the top of the Formation (Gardiner & Reynolds 1909, 1910; Dewey *et al.* 1970). The underlying Mount Partry Beds have yielded Lower Arenig graptolites (*D. nitidus* Zone), confirming that the age span of the successions of the Tourmakeady and Glensaul inliers, which together constitute the Glensaul Group (Williams *et al.* 1972), lies entirely within the Arenig.

The Tourmakeady Limestone fossils have also been recovered from several exposures of the enclosing calcareous tuffs in both inliers (Fig. 1) and, although less well preserved than the etched specimens, are clearly conspecific, and almost certainly contemporaneous. The disjunct outcrops of the Tourmakeady Limestone suggest that the Member was initially in more continuous sheets along the postulated fault-controlled southern margin of the 'South Mayo Trough', but was fractured and dislocated shortly after lithification, and then rafted as dispersed blocks at a time when contemporaneous vulcanicity was generating considerable quantities of quartz and feldspar porphyry and feeding submarine flows of tuffs and associated clastic sediments.

The brachiopods from the Tourmakeady Limestone display strong North American affinities. Excluding new genera, over 50% of the Tourmakeady genera were included by Ulrich & Cooper (1938) in their survey of Upper Cambrian and Lower Ordovician brachiopods from North America, while a further 45% of the previously-established Tourmakeady genera occur in younger Ordovician successions in that continent (Cooper 1956). Nearly a third of the brachiopod genera occurring in the richly fossiliferous Lower Ordovician Antelope Valley Limestone at Meiklejohn Peak, Nevada (Ross 1972; Krause & Rowell 1975) are represented in the Tourmakeady Limestone. Such correlation, which emphasizes the faunal continuity within the Scoto-Appalachian (or American) Province (Williams 1969), contrasts markedly with comparisons between the Tourmakeady faunal lists and those from outcrops within other Lower Ordovician faunal provinces (Williams 1973). Thus out of 28 genera recorded from Arenig successions (Celtic province) in New World Island (Neuman 1976) only *Multispinula*, *Orthambonites* and *Tritoechia* are common to the

Fig. 1 Summary geological map of the Tourmakeady-Glensaul districts, Co. Mayo, Republic of Ireland, showing fossil location referred to as Loc. 1 in text.

# GEOLOGY MAP OF THE GLENSAUL Gp. (ARENIG), Co. MAYO



**KEY**

-  Shangort & Tourmakeady Beds
-  Mount Partry Beds

-  Quartz/Feldspar porphyry

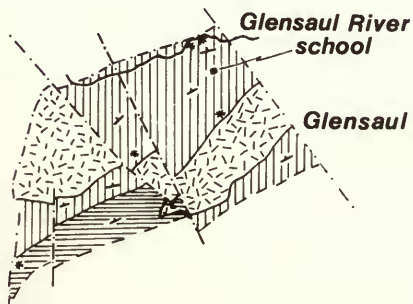
- \* fossil locality

- - - fault

- / - bedding

- - - boundary

- - - - - inferred boundary



Lough Mask





Mayo successions. The last two genera are again the only taxa found in both the Tourmakeady Limestone and in early Ordovician rocks from Anglesey, North Wales (Neuman & Bates 1978). Recent descriptions of the Lower Ordovician faunas from the Montagne Noire, France (the Anglo-French province), reveals only one common articulate (*Orthambonites*) and three inarticulate genera (Havlíček 1980, Babin *et al.* 1982) out of a total fauna of 17 genera. Similarly, the distinction between the Tourmakeady fossils and those from contemporaneous rocks within the Baltic province is equally apparent (e.g. Neuman & Bruton 1974, Bruton & Harper 1981). In view of the pandemic distribution of *Orthambonites* and *Tritoechia*, it seems reasonable to assume that the many new taxa described in this paper were really part of the benthic faunas of the American Province and have yet to be discovered in association with the better-known species outside County Mayo.

### Type locality and horizon

Unless otherwise stated, the type horizon and locality of all new species we describe herein is: Tourmakeady Limestone; banks of un-named stream, 2 km south-west of Srah Bridge, Co. Mayo, Republic of Ireland (Loc. 1; Grid reference M 105719). See Fig. 1.

### Systematic methods and terminology

The recovery of large numbers of isolated complete valves from the Tourmakeady Limestone provides the means to augment standard qualitative systematic procedures with bivariate analysis of the shell parameters normally used for taxonomic differentiation. Standardization of the statistical methodology utilized in such analyses, and of the method of data presentation, allows comparisons with other samples, and also provides a rigorous framework for assessing evolutionary trends. Accordingly the statistical procedures adopted herein are those used in other studies of Ordovician brachiopods (e.g. Williams 1974, Lockley & Williams 1981). The taxonomic weight given to statistically significant differences in skeletal morphology is that described by Williams (1962: 70–79). In addition the resulting data have been presented in the same way as those used by Lockley & Williams (1981). The mean, variance and number of measurements have been incorporated directly into the systematic descriptions, and when expressed as bivariates are accompanied by the appropriate coefficients of correlation ( $r$ ).

The following abbreviations have been used in the text, referring to shell features measured in millimetres:  $l$  ( $\bar{l}$ ) maximum length (and mean);  $w$  ( $\bar{w}$ ) maximum width (and mean);  $th$  ( $\bar{th}$ ) maximum shell depth (and mean);  $l_s$  ( $\bar{l}_s$ ) maximum length of median septum or ridge (and mean);  $l_{sc}$  ( $\bar{l}_{sc}$ ) maximum length of muscle scars (and mean);  $l_{te}$  ( $\bar{l}_{te}$ ) maximum length of teeth (and mean);  $l_b$  ( $\bar{l}_b$ ) maximum length of brachiophores or brachiophore bases (and mean);  $w_{so}$  ( $\bar{w}_{so}$ ) maximum width of socket ridges (and mean);  $l_n$  ( $\bar{l}_n$ ) maximum length of notothyrial platform (and mean);  $l_p$  ( $\bar{l}_p$ ) maximum length of pseudospondylium (and mean);  $l_{sp}$  ( $\bar{l}_{sp}$ ) maximum length of spondylium (and mean);  $l_{in}$  ( $\bar{l}_{in}$ ) maximum length of interarea (and mean);  $l_{lp}$  ( $\bar{l}_{lp}$ ) maximum length of lophophore platform (and mean).

All specimens have been deposited in the British Museum (Natural History). The registration numbers quoted in the text, with the prefix BB, refer to the fossil Brachiopoda collections in the Department of Palaeontology of that institution.

### Taxonomic descriptions

Class INARTICULATA Huxley, 1869

Order LINGULIDA Waagen, 1885

Superfamily LINGULACEA Menke, 1828



Family **OBOLIDAE** King, 1846

Subfamily **OBOLINAE** King, 1846

Genus ***DICTYOBOLUS*** nov.

**DIAGNOSIS.** CONVEXO-plane to unequally biconvex obolids, with truncated posterior margins, young valves semicircular in outline becoming transversely oval in later stages of growth with more obtuse cardinal extremities; shell surface ornamented by distally rounded, slightly everted concentric lamellae and two superimposed sets of obliquely-disposed fine ridges intersecting in an acutely rhombic microscopic pattern.

Ventral interior with strong, apsacline pseudointerarea divided into narrowly triangular propareas by a pedicle groove consisting of a sunken concave plate with free, rounded anterior margins; muscle scars forming arc of oblique and median impressions interrupted by divergent *vascula lateralia*.

Dorsal interior with anacline pseudointerarea thickened and indented medially by a broad shallow depression; muscle impressions unknown.

**NAME.** Greek, *δίπτυον*, a net.

**TYPE SPECIES.** *Dictyobolus transversus* sp. nov. from the Tourmakeady Limestone, Co. Mayo.

**DISCUSSION.** The combination of transversely oval shape, elevated concentric ornamentation, and strong divided pseudointerareas in both valves, indicates that the obolid *Dictyobolus* is most appropriately assigned to the Obolinae. Within that subfamily *Dictyobolus* is readily distinguishable from all other obolines by the presence of the sunken median plate in the ventral pseudointerarea, and its distinctive ornamentation. In shape, *Dictyobolus* is comparable to *Obolus* Eichwald and *Thysanotos* Mickwitz, but *Obolus* has a narrow pedicle groove and lacks strong concentric ornamentation, whilst the elevated ornamentation of *Thysanotos* bears regular rows of fine spines.

Differences in ornamentation and in the structure of the ventral and dorsal pseudointerarea serve to distinguish *Dictyobolus* from *Dicellomus* Hall and *Pseudodicellomus* Bell.

*Palaeobolus* Matthew and *Aulonotreta* Kutorga also have elevated concentric ornamentation which, however, differs from that of *Dictyobolus* in being discontinuously developed, especially in *Aulonotreta*. In addition, both genera have elongate, strongly biconvex shells which immediately distinguish them from *Dictyobolus*.

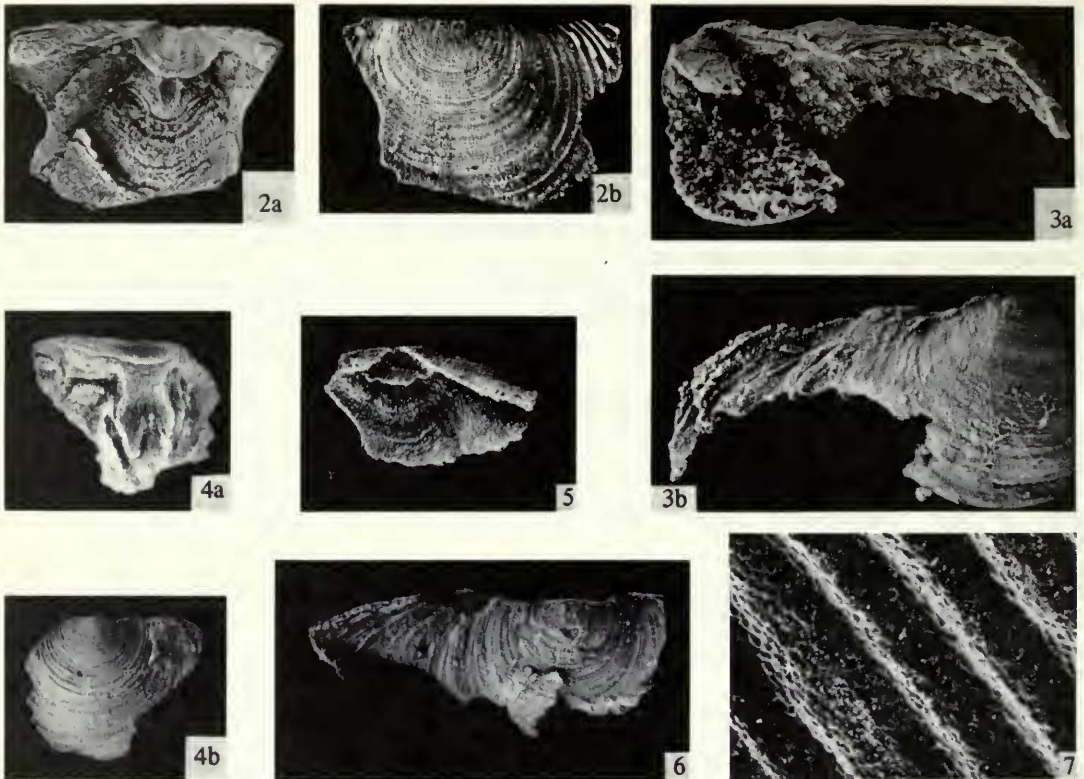
*Dictyobolus transversus* sp. nov.

Figs 2-7

**DIAGNOSIS.** Thick-shelled *Dictyobolus* ornamented by concentric lamellae with wavelength and amplitude of 0.1 mm at 2 mm anterior of ventral umbo, and two intersecting sets of fine ridges forming acutely rhombic pattern with dimensions of  $70 \times 25 \mu\text{m}$  medially; composite arcuate muscle scar, convex anteriorly, impressed posteromedially in the pedicle valve.

**NAME.** 'Crosswise'.

**DESCRIPTION.** Medium-sized convexo-plane to unequally biconvex *Dictyobolus*, estimated to have attained a maximum length and width of c. 7.5 mm and 12 mm respectively. Juvenile shells semicircular, about 85% as long as wide, becoming transversely oval in later growth stages and 65% as long as wide; cardinal extremities of truncated posterior margin obtusely rounded at 150°, anterior margins of valves rectimarginate, truncated, becoming smoothly rounded anterolaterally; ornamented by strong, elevated concentric lamellae rounded distally and everted slightly posteriorly, with wavelength and amplitude of 0.1 mm at 2 mm anteromedially of ventral umbo; lamellae in adult shells most strongly developed anteromedially and anterolaterally, with wavelengths up to 0.4 mm and amplitudes up to 0.3 mm and commonly interspersed with secondary lamellae; external valve surfaces further ornamented



**Figs 2-7** *Dictyobolus transversus* gen. et sp. nov. Fig. 2a, b, holotype BB 95387, interior and exterior of incomplete pedicle valve, both  $\times 7$ ; Fig. 3a, b, paratype BB 95391, interior and exterior of incomplete pedicle valve, both  $\times 6$ ; Fig. 4a, b, paratype BB 95392, interior and exterior of incomplete brachial valve, both  $\times 6$ ; Fig. 5, paratype BB 95389, interior of pedicle valve,  $\times 7$ ; Fig. 6, paratype BB 95388, exterior of incomplete pedicle valve,  $\times 6$ ; Fig. 7, paratype BB 95519, detail of external ornamentation,  $\times 90$ .

by two sets of obliquely-disposed fine ridges with wavelength of  $25\mu\text{m}$  and amplitude of  $5\mu\text{m}$ , intersecting to form acutely rhombic pattern about  $70 \times 25\mu\text{m}$  medially.

Interior of pedicle valve with thickened apsacline pseudointerarea divided into narrowly triangular propareas by shallowly concave pedicle groove, propareas strongly grooved by growth-lines, especially posterolaterally; pedicle groove defined by broad, semicircular, sunken plate ankylosed with floor of valve posteriorly but becoming free anteriorly and anterolaterally, plate finely grooved by concentric growth-lines and 57% as long as wide in two specimens; composite arcuate muscle scars, convex anteriorly and 39% as long as wide in two specimens impressed posteromedially but interrupted by divergent branches of *vascula lateralia*; paired median muscle scars symmetrically disposed about median axis of valve and separated from posterolaterally-situated oblique muscles by canals of *vascula lateralia* about 2mm wide, axes of *vascula lateralia* diverging anteriorly at angle of  $35^\circ$  to median axis of valve.

Dorsal pseudointerarea wide, thickened, anacline, and divided into well-defined propareas by broad, shallowly concave, median depression 2.6mm wide; shell strongly thickened posteriorly, rising up to buttress elevated anterior margin of median depression.

**HOLOTYPE.** Incomplete pedicle valve, BB 95387. Fig. 2.

**PARATYPES.** Incomplete pedicle valves, BB 95389-91; incomplete brachial valves, BB 95388, 95392; fragments, BB 95519-20.

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. The new genus *Dictyobolus* is at present monospecific, and only known from over 80 incomplete specimens recovered from the etched residues from the Tourmakeady Limestone. Among described species, only *Obolus* sp. 3 from the Pratt Ferry Formation of Alabama (Cooper 1956: 163) has the transversely oval shape and strong elevated concentric ornamentation characteristic of *D. transversa* and may well belong to the new genus. The internal structures of this species are, however, unknown, and there is no record of the superimposed pattern of intersecting fine ridges so characteristic of the Irish genus.

Genus *LINGULOBOLUS* Matthew 1895

*Lingulobolus septatus* sp. nov.

Figs 8–10

DIAGNOSIS. Strongly biconvex *Lingulobolus* lacking radial ornamentation and internally with short median septum and two short lateral septa anterior of the pedicle groove.

NAME. 'With septa'.

DESCRIPTION. Medium-sized, elongately oval dorsibiconvex *Lingulobolus* attaining maximum size of 10–12 mm; external surfaces with rare, fine concentric growth-lines; pedicle valve with subacuminate posterior margin, moderately convex medially becoming less convex peripherally; posterior margin of brachial valve obtusely rounded; shell substance lamellar.

Interior of pedicle valve with broadly triangular pseudointerarea, strongly thickened medially and divided into small triangular propleas by broad triangular pedicle groove; propleas thin-shelled, elevated above valve floor, and forming dorsal margins of deep umbonal cavities approximately 0.5 mm in maximum diameter; pedicle groove shallowly concave, about 50% as wide as long in two specimens, with strongly thickened anterior margin ankylosed with, and elevated above, floor of valve; pedicle groove buttressed anteriorly by short median septum and two short lateral septa; paired, broadly oval, transmedian muscle scars shallowly impressed on floor of valve lateral of median septum; single circular pedicle muscle (?) scar impressed anteromedially on pedicle groove.

Dorsal pseudointerarea narrow, undivided, and recurved posteromedially; floor of brachial valve with broad, low, narrowly triangular median septum first discernible about 0.5 mm anterior of pseudointerarea and becoming progressively wider and thicker anteriorly; median septum slightly bilobed anteriorly, with superimposed low, rounded, median ridge up to 0.3 mm wide; strong, paired, oval transmedian muscle scars (presumably associated with outside and middle laterals) impressed posterolateral of the posterior margin of the median septum; anterior to these another pair of scars probably representing central muscle bases; narrow depression immediately anterior of median septum probably the attachment site of anterolateral muscles; paired umbonal muscles, tear-shaped and about three times as long as wide, deeply impressed anterolaterally of dorsal pseudointerarea, margins of umbonal muscle scars defined posteriorly by narrow, slightly elevated, ridge of shell, and anteriorly by strongly-developed, posteriorly-reclining anteromedian wall strongly thickened posteriorly; muscle scar bases grooved by growth-lines.

HOLOTYPE. Incomplete brachial valve, BB 95397. Fig. 8.

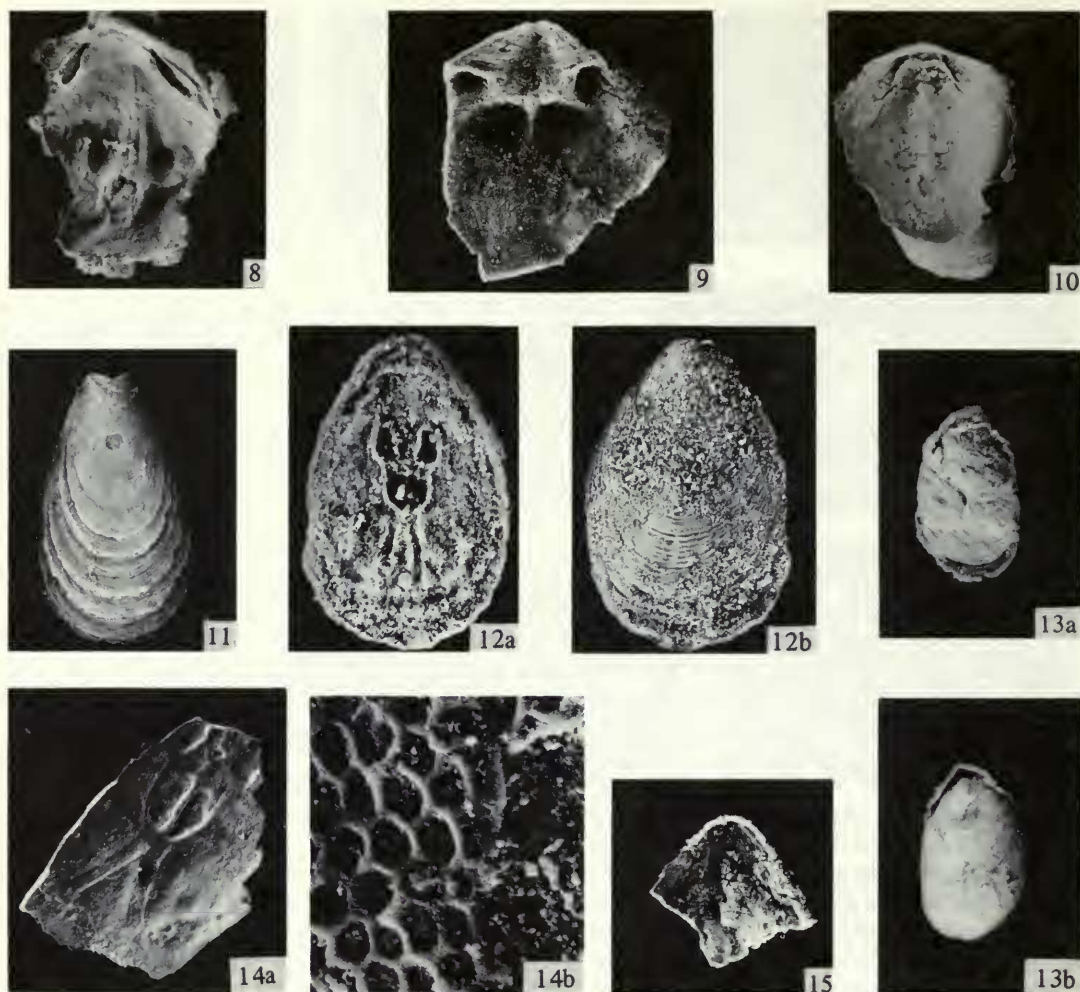
PARATYPES. Incomplete pedicle valve, BB 95398; incomplete brachial valve, BB 95399.

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. Differences in shape, external ornamentation, and internal structure of the pedicle valve serve to distinguish *L. septatus* from all described species of this rare genus.

*L. spissus* (Billings) from the Lower Ordovician of Newfoundland (Walcott 1912: 432) is similar to *L. septatus* in being dorsibiconvex and, in the brachial valve, in having strong umbonal muscle scars and a broad, low, median septum flanked by deeply impressed muscle





**Figs 8–10** *Lingulobolus septatus* sp. nov. Fig. 8, **holotype** BB 95397, interior of incomplete brachial valve,  $\times 6$ ; Fig. 9, paratype BB 95398, interior of incomplete pedicle valve,  $\times 7$ ; Fig. 10, paratype BB 95399, interior of incomplete brachial valve,  $\times 4$ .

**Figs 11–15** *Lingulella hespera* sp. nov. Fig. 11, **holotype** BB 95393, exterior of incomplete pedicle valve,  $\times 5$ ; Fig. 12a, b, paratype BB 95395, interior and exterior of pedicle valve, both  $\times 7$ ; Fig. 13a, b, paratype BB 95394, dorsal and ventral views of juvenile conjoined valves, both  $\times 12$ ; Fig. 14a, b, paratype BB 95475, interior of incomplete pedicle valve: a,  $\times 15$ ; b, detail of epithelial moulds on shell interior,  $\times 640$ ; Fig. 15, paratype BB 95396, interior of incomplete brachial valve,  $\times 8$ .

scars. The structure of the dorsal pseudointerarea is also similar in both species, being narrow and recurved posteriorly. However, *L. septatus* differs from the Canadian species in having median and lateral septa in the pedicle valve, and in the absence of radial ornamentation externally.

*L. septatus* can readily be distinguished from *Obolus* (*Lingulobolus*) *affinis* (Billings), also from the Lower Ordovician of Newfoundland (Walcott 1912: 433), as the latter is triangular in shape, has strong external radial ornamentation, and lacks septa in the pedicle valve.

*Lingulobolus* has also been recorded from Europe. *Obolus* (*Lingulobolus*) *feistmanteli* (Kohila) from the Lower Ordovician of Poland, according to poorly illustrated material



figured by Bednarčzyk (1964), differs from *L. septatus* in having a much more acuminate posterior margin, a wider dorsal pseudointerarea, and umbonal muscle scars situated much closer to the median axis of the brachial valve. *L. brimonti* (Rouault) from the Lower Ordovician of France and ? north Africa (Havlíček 1980: 3) and *L. hawkei* (Rouault) from the Lower Ordovician of France and Lower Ordovician pebbles in the Triassic Budleigh Salterton Pebble Bed of England (Davidson 1866: 41; Cocks & Lockley 1981: 113) have much stronger concentric ornamentation, and also differ from *L. septatus* in internal morphology.

Subfamily LINGULELLINAE Schuchert 1893

Genus LINGULELLA Salter 1866

*Lingulella hesperia* sp. nov.

Figs 11–15

DIAGNOSIS. Subtriangular *Lingulella* broadening to almost three-fifths as wide as long in anterior half of shell, anterior margin rounded, lateral margins gently rounded, tapering to become progressively acuminate posteriorly.

NAME. 'Western'.

DESCRIPTION. Medium-sized elongately subtriangular biconvex *Lingulella* 57% as wide as long in two specimens and attaining lengths of at least 7–8 mm; shell with maximum width anteriorly and tapering smoothly posteriorly; lateral margins of valves smoothly rounded and subparallel, especially in juvenile stages of growth; external ornamentation consisting of variably developed concentric growth-lines and fine, evenly-spaced, concentric fila numbering 12–16 per mm.

Pedicle valve moderately to strongly convex with sharply tapering subacuminate posterior margin and smoothly rounded anterior margin; pseudointerarea adnate with triangular propareas defined by weak flexure lines, propareas separated by broad pedicle groove up to 0.4 mm wide and only slightly elevated above valve floor, pedicle groove and propareas marked by fine growth-lines, anterior margins of propareas thin-shelled, slightly elevated above valve floor, and extended anteromedially as small semicircular lobes 0.2 mm in diameter; two sets of longitudinally ovate muscle scars, with dimensions of 0.7 × 0.4 mm and 0.5 × 0.2 mm in two specimens, strongly impressed symmetrically on either side of median axis of valve, posteriormost set of muscle scars tapering sharply posteriorly and slightly bilobed anteriorly, with lateral separation of 0.5 mm and 0.4 mm in two specimens as compared with 0.1 mm for anterior pair in both specimens; two sets of aligned, elongately oval, cardinal muscle scars, with dimensions of 0.5 × 0.25 mm, deeply impressed slightly anterior of propareas; *vascula lateralia* as two parallel-sided canals, 1 mm long × 0.1 mm wide, strongly impressed anteriorly of muscle field, flanking faint elongate tear-shaped median depression; canals diverging anteriorly at 20° to median axis of valve.

Brachial valve moderately to strongly convex with rounded acuminate posterior margin and smoothly rounded anterior margin; dorsal pseudointerarea anacline, undivided, very narrow in juveniles but becoming wider, thickened, and posteriorly truncated (?) in adults.

HOLOTYPE. Incomplete pedicle valve, BB 95393. Fig. 11.

PARATYPES. Conjoined juvenile valves, BB 95394a, b (length 2.7 mm, width 1.6 mm). Pedicle valve, BB 95395 (length 5.8 mm, width 3.2 mm); incomplete pedicle valves, BB 95475, 95521. Incomplete brachial valve, BB 95396.

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. Three *Lingulella* species from the Ordovician of North America have a broadly similar outline to that of the Tourmakeady specimens. They are *L. vermontensis* Ulrich &

Cooper, from the Providence Island Limestone of Vermont (Ulrich & Cooper 1938: 51), *L. lirata* from the Pratt Ferry Formation of Alabama (Cooper 1956: 201), and *L. spicata* Cooper from the Whitesburg Formation of Tennessee (Cooper 1956: 204). However, all three species, which are much larger than *L. hesperia*, have a much more acuminate posterior margin and a much narrower pedicle groove. Other species of *Lingulella* are less triangular in outline and also differ in other features. For example, *L. hesperia* can additionally be distinguished from *L. bullata* Krause & Rowell (1975: 15), from the Ordovician Antelope Valley Limestone in southern Nevada, in that the latter has a narrow submarginal ridge in both valves. The pedicle groove of *L. cf. zeuschneri* Bednarčzyk from the Tremadoc of Poland (Biernat 1973: 56) is much narrower than that of the Irish species, and the posterior margin of the pedicle valve is more strongly acuminate. *L. (Leptembolos) lingulaeformis* (Mickwitz) from the Cambro-Ordovician of the Russian Platform (Goryanskyii 1969: 38) has a tapering subacuminate posterior margin similar to that of *L. hesperia*, but is much broader anteriorly.

The heterogeneous nature of the shell fabric of *Lingulella* may explain the variable degree of convexity of the Tourmakeady valves (Curry & Williams 1983). In living *Lingula* the different coefficient of contraction of the apatite as compared to the organic layers of the valves frequently results in strong distortion of the shell profile in dried specimens. Similar distortions are found in some of the Irish valves are excessively arched about the long median axis.

### Genus *WESTONIA* Walcott, 1901

#### *Westonia* sp.

#### Figs 16–17

**DIAGNOSIS.** Broadly oval (?) *Westonia* with truncated posterior margin to pedicle valve, open, reticulate ornamentation, and low, tongue-like, platform extending anteriorly of pedicle groove.

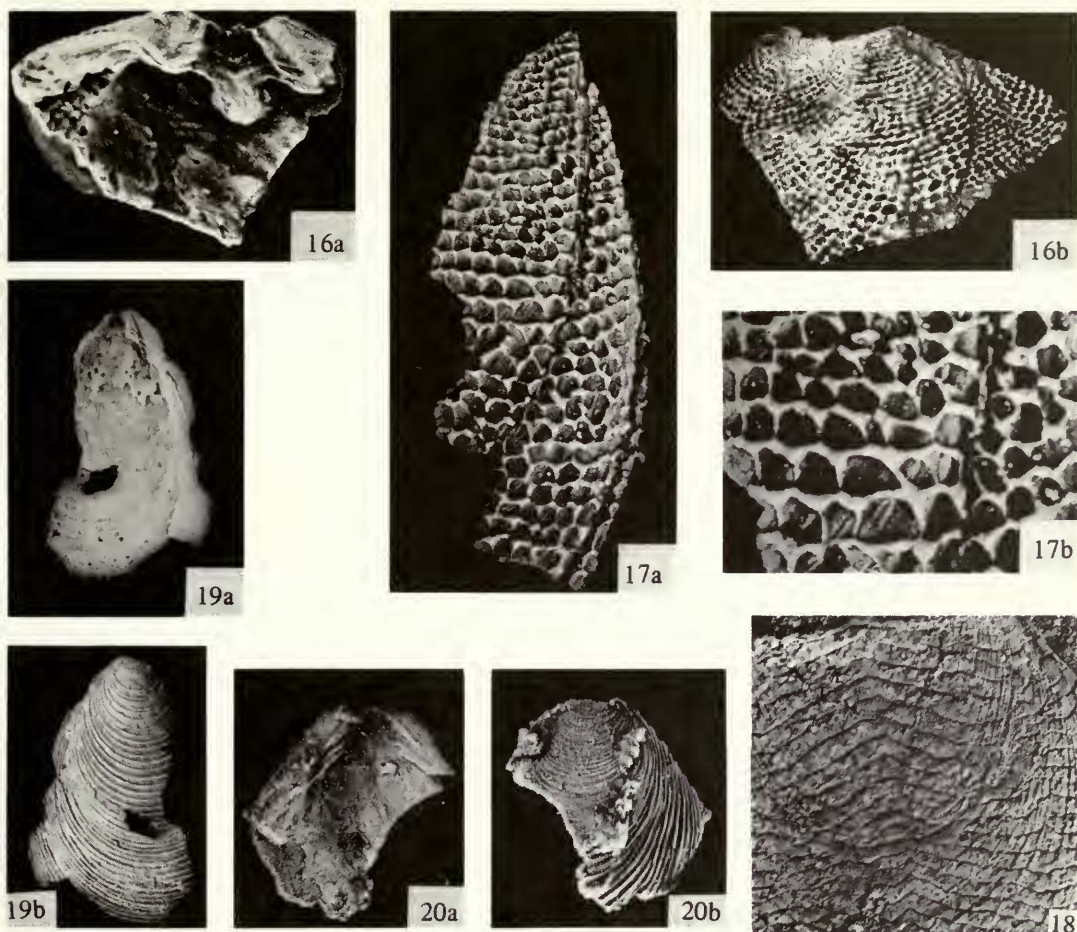
**DESCRIPTION.** Residues from etched blocks of Tourmakeady Limestone have yielded a few fragments of an inarticulate species, including a well-preserved posterior portion of a pedicle valve, all characterized by the distinctive external ornamentation of *Westonia*. Reconstructions suggest that the convex valves were broadly oval in outline, and approximately 15–18 mm long. The external surfaces are ornamented with rare, strong, concentric growth-lines, and two sets of narrowly rounded rugae with a wavelength of approximately 0.25 mm and an amplitude of approximately 0.75 mm at 3 mm anterior of umbo. Each set curves obliquely across the valve surface from the posterolateral margin to intersect with the opposite anterolateral margin at approximately 30°–50°. The intersection of these two sets of rugae gives rise to a delicate, lace-like, reticulate pattern. The pattern is first discernible about 2 mm anterior of the umbo, and the reticulations, commonly with curved posterior borders thickened at the junction, are approximately 0.2 mm square in the median region of the valve, 3 mm anterior of the ventral umbo.

In the interior of the pedicle valve the ventral pseudointerarea is wide, grooved by growth-lines, and divided into well-defined propleas by a shallow pedicle groove about 1.6 mm wide. The propleas are swollen immediately lateral to the pedicle groove and project anteriorly as a pair of rounded platforms. The triangular pedicle groove extends anteriorly as a broad, tongue-shaped plate ankylosed with the floor of the valve.

**FIGURED MATERIAL.** Incomplete pedicle valve, BB 95384; incomplete valve, BB 95385. Loc. 1.

**DISCUSSION.** Several *Westonia* species have been recorded from the Cambro-Ordovician successions of North America, but only *W. superba* Cooper and *W. sp. 1* (Cooper 1956: 209) have an ornamentation comparable with the Irish material, albeit with more strongly developed rugae. The Tourmakeady *Westonia* can readily be distinguished from *W. linguloides* (Kobayashi), from the Upper Cambrian Limestones of Alaska (see Ulrich &





**Figs 16–17** *Westonia* sp. Fig. 16a, b, BB 95384, interior and exterior of incomplete brachial valve,  $\times 7$ ; Fig. 17a, b, BB 95385, exterior of fragment: a,  $\times 10$ ; b, ornamentation  $\times 30$ .

**Fig. 18** *Westonia olliis* (Whitfield). St Croix Sandstone, Wisconsin, U.S.A. USNM 27394, latex peel of exterior,  $\times 10$ .

**Figs 19–20** *Plectoglossa* sp. Fig. 19a, b, BB 95406, interior and exterior of incomplete pedicle valve, both  $\times 4$ ; Fig. 20a, b, BB 95407, interior and exterior of incomplete pedicle valve, both  $\times 7$ .

Cooper 1938: 56), and *W. pupyshevi* Popov, from the Ordovician of Kazakhstan (Popov 1980: 84), both of which have a different ornamentation and a tapering triangular posterior margin to the pedicle valve. *Westonia* has also been described from the Cambro-Ordovician of the Russian Platform (Goryanskiĭ 1969: 40), and the Arenig of Estonia (Biernat 1973: 57). In both cases the pattern of ornamentation and shape of the ventral umbo are different, and there is no plate anterior to the pedicle groove.

The external ornamentation of *Westonia* is commonly described as being 'distinguished by peculiar, transverse, semi-imbricating, "ripple-embossed" lines that cross both concentric and radial striae' (Walcott 1912: 378). This is in contrast to the two oblique sets of rugae on the Irish *Westonia*. Moreover the development of a transverse ornamentation at right angles to the median axis of the valve and cutting across growth-lines is very difficult to rationalize in terms of the concentric growth of the valve margin. However, a detailed examination of some Upper Cambrian *Westonia* has indicated that the transverse ornamentation may be an

artefact. For example, flattened specimens of *W. olli* (Whitfield) from the St Croix Sandstone of Wisconsin (Walcott 1912: 465, figured on pl. XLIX as *W. stoneanus*) do indeed have a variably-developed transverse ornamentation of small scarps, forming either an irregularly transverse or zig-zag pattern medially (see Fig. 18). This pattern can be produced by the compression, during diagenesis, of convex shells composed of thin layers of apatite which can move slightly relative to one another on interleaved organic sheets and which break along crystallographically defined lines. However, a close inspection of valve surfaces of *W. olli* also reveals two oblique sets of rugae (Fig. 18), each running obliquely across the valve from the posterolateral margin to the opposite anterolateral margin, exactly as described for the Irish *Westonia*. It seems probable, therefore, that the diagnostic ornamentation of undeformed *Westonia* consists of oblique rugae unaccompanied by transverse components.

Subfamily GLOSSELLINAE Cooper, 1956

Genus PLECTOGLOSSA Cooper, 1956

*Plectoglossa* ? sp.

Figs 19–20

Several fragments and a few incomplete valves of a distinctively ornamented glosselline species have been recovered from the Tourmakeady Limestone at Loc. 1, which are provisionally assigned to *Plectoglossa*. The largest specimen (BB 95406), a broken pedicle valve estimated to have been about 10 mm long and 7.5 mm wide when complete, has a tapering posterior margin and smoothly rounded anterior and lateral margins. On the basis of the available material it appears that the pedicle valve is gently and smoothly convex in lateral profile, and moderately to strongly convex in anterior profile. The external ornamentation is very distinctive, with prominent, evenly-spaced, elevated concentric fila averaging 5 per mm (range 4–6) over the postneanic surface of the valve. On the interior of the pedicle valve the ventral pseudointerarea is thickened, grooved by growth-lines, and divided into a pair of narrowly triangular propleas by strong flexure lines. The ventral propleas are separated by a broadly triangular, flat-lying, concave pedicle groove. Confirmation of this arrangement is seen on another incomplete pedicle valve assignable to the species (BB 95407).

In size, shape, and external ornamentation the Tourmakeady specimens are similar to typical *Plectoglossa* (Cooper 1956: 222) from the Ordovician of North America. However, the median fold in the pedicle groove which is said to be diagnostic of the genus is not evident in any of the pedicle valve fragments recovered from the Tourmakeady residues. Although the Irish material is somewhat abraded, it is not conceivable that this feature has been obscured by erosion, but in view of the inadequate sample it seems wiser to withhold full taxonomic recognition for the present, and provisionally to assign the specimens to *Plectoglossa* on the basis of the clear external similarities outlined above.

Subfamily ACANTHAMBONIINAE Cooper, 1956

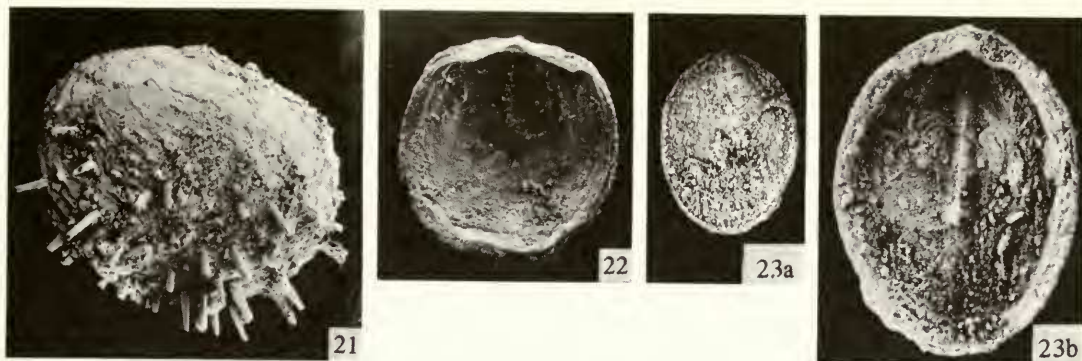
Genus ACANTHAMBONIA Cooper, 1956

*Acanthambonia* sp.

Figs 21–22

The Tourmakeady Limestone exposed at Loc. 1 yielded two examples of the rare obolid genus *Acanthambonia*. The specimens (BB 95445–46) are almost circular in outline, the larger measuring 3.2 mm in length and 3.1 mm in width, with smoothly rounded lateral and





**Figs 21–22** *Acanthambonia* sp. Fig. 21, BB 95446, exterior of brachial valve,  $\times 14$ ; Fig. 22, BB 95445, interior of brachial valve,  $\times 9$ .  
**Fig. 23a, b** *Elliptoglossa* sp. BB 95405, exterior and interior of brachial valve: a,  $\times 3$ ; b,  $\times 5$ .

anterior margins. The posterior margin is gently rounded and slightly truncated. In lateral profile the valves are moderately convex. The external surfaces are ornamented by fine concentric growth-lines and scattered, hollow, erect spines with a maximum diameter of  $100\mu\text{m}$ . On the interior of the brachial valve the dorsal pseudointerarea is well developed, and folded medially to form a rounded, convex, ridge.

In shape, disposition and size of external spines, and form of dorsal pseudointerarea, the Tourmakeady valves are similar to *A. minutissima* Cooper (1956: 212), the type species of the genus from the Middle Ordovician Pratt Ferry Formation of Alabama. Some differences are discernible, however. In particular the Tourmakeady specimens are larger, much thicker shelled, and have wider dorsal pseudointerarea, but until the consistency of these differences can be confirmed or refuted in a larger sample, specific identification is withheld.

Family **PATERULIDAE** Cooper, 1956

Genus **ELLIPTOGLOSSA** Cooper, 1956

*Elliptoglossa* sp.

Fig. 23

**DIAGNOSIS.** Large, thick-shelled *Elliptoglossa*, with long, low, median septum in brachial valve; dorsal limbus arched posteromedially into narrow, ventrally convex, fold.

**DESCRIPTION.** Large, elongately-oval *Elliptoglossa*, 76% as wide as long; lateral and anterior margins smoothly rounded, with slightly tapering, obtusely rounded, posterior margin; brachial valve gently convex in lateral profile, becoming less convex anteriorly; dorsal umbo swollen, beak projecting posteriorly beyond posterior margin of valve; external surfaces strongly mineralized, but concentric growth-lines are apparent here and there.

Interior of brachial valve with strongly-developed, flattened, marginal limbus up to 0.7 mm wide posteromedially but becoming less strongly developed anteriorly and anterolaterally; limbus elevated above floor of valve posteriorly and posterolaterally, and arched posteromedially into narrow, ventrally convex, fold of shell; floor of brachial valve with low median septum extending anteriorly for about 55% of valve length from beneath limbus; median septum with maximum width of 0.8 mm posteriorly, becoming narrower and slightly more elevated anteriorly; pair of arcuate transmedian (?) muscle scars, convex posteriorly and with maximum width of 0.8 mm, impressed symmetrically on either side of median septum, 2.4 mm anterior of posterior margin of valve.

FIGURED MATERIAL. Complete brachial valve, BB 95405: length 8.2 mm, width 6.2 mm. Loc. 1.

DISCUSSION. The available material consists of a single strongly mineralized brachial valve. The elongately-oval shape, strongly developed limbus and posteriorly convex muscle scars of the Irish specimen suggest a close affinity with *E. ovalis* Cooper, the type species of *Elliptoglossa*, from the Ordovician of the north-eastern U.S.A. (Cooper 1956: 242). However, the Tourmakeady specimen can readily be distinguished from *E. ovalis*, as the latter has a much shorter median septum which does not extend posteriorly of the muscle scars, and lacks a posteromedian fold in the limbus. The Tourmakeady *Elliptoglossa* differs from *E. sylvanica* Cooper, from the Ordovician of North America (Cooper 1956: 244) and the U.S.S.R. (Popov 1980: 80), in having a median septum in the brachial valve.

While the distinctive morphology of the Irish *Elliptoglossa* suggests that it represents a new species, the fact that only one specimen has been recovered precludes formal recognition.

Order ACROTRETIDA Kuhn, 1949

Suborder ACROTRETINA Kuhn, 1949

Superfamily ACROTRETACEA Schuchert, 1893

Family ACROTRETIDAE Schuchert, 1893

Subfamily ACROTRETINAE Schuchert, 1893

Genus *CONOTRETA* Walcott, 1889

*Conotreta lepton* sp. nov.

Figs 24–27

DIAGNOSIS. Minute, thin-shelled, transversely oval to subcircular *Conotreta* with moderately conical pedicle valve about three-quarters as long as wide and half as high as wide; brachial valve gently convex, about four-fifths as long as wide and one-tenth as deep as wide; dorsal median septum simple, blade-like, extending about three-fifths of valve length.

NAME. Greek, *λεπτόν*, a small coin.

DESCRIPTION. Minute, thin-shelled, transversely oval to subcircular *Conotreta*, translucent to pale green in colour, with smoothly and evenly rounded anterior and lateral margins and straight posterior margin; pedicle valve averaging 74% as long as wide at commissure ( $\bar{l}$  mm (var l) 1.21 (0.05),  $\bar{w}$  mm (var w) 1.65 (0.10),  $r = 0.941$ ;  $n = 8$ ) with moderately conical lateral profile averaging 47% as high as wide at posterior margin ( $\bar{th}$  mm (var th) 0.78 (0.02),  $\bar{w}$  mm (var w) 1.65 (0.10),  $r = 0.910$ ;  $n = 8$ ); external surfaces ornamented by fine concentric lamellae numbering 24 per 100  $\mu$ m at 100  $\mu$ m anteromedially of ventral umbo; apex of pedicle valve situated posteriorly, with prominent, conical, protegulum, circular in outline and averaging 11% as long as valve in two specimens; external surface of protegulum with evenly spaced circular pits ranging 1.6–2.4  $\mu$ m in diameter; minute, circular pedicle foramen, 23  $\mu$ m and 25  $\mu$ m in diameter in two specimens, situated slightly posteriorly of rounded apex of protegulum, at end of short, circular pedicle tube directed obliquely posteroventrally to overhang flattened, triangular, apsacline to procline pseudointerarea which is not divided medially; interior of pedicle valve with prominent apical process as boss of shell developed along anteroventral slope of valve and forming anterior wall of transversely oval internal pedicle opening.

Brachial valve transversely elliptical in outline, averaging 80% as long as wide ( $\bar{l}$  mm (var l) 1.39 (0.08),  $\bar{w}$  mm (var w) 1.74 (0.13),  $r = 0.977$ ;  $n = 7$ ), gently and smoothly convex in lateral profile, broadly convex in anterior profile with flattened margins, and averaging 11%

as deep (th) as wide ( $\bar{th}$  mm (var th) 0.16 (0.01),  $\bar{w}$  mm (var w) 1.74 (0.13),  $r = 0.801$ ;  $n = 7$ ); dorsal umbo rounded, triangular, beak projecting posteriorly of posterior margin of valve; interior of brachial valve with short, concave, anacline pseudointerarea separating narrowly triangular propleareas; posterior margin of pseudointerarea rounded, anteriorly convex, elevated above floor of valve and medially buttressed to floor of valve by large, thickened, rounded boss of shell; floor of brachial valve with short, low, blade-like median septum extending anteriorly from median buttress in juveniles but subject to strong resorption along its posterior slope during growth and becoming separated from median buttress in adults and progressively more triangular in lateral profile; median septum (ls) extending anteriorly on average 60% of valve length ( $\bar{l}$  mm (var l) 1.39 (0.08),  $\bar{l}_s$  mm (var  $l_s$ ) 0.83 (0.03),  $r = 0.963$ ;  $n = 7$ ); apex of triangular median septum situated posteriorly, rounded and thickened, and may be extended posteroventrally or anteroventrally as short, erect, cylindrical rod of shell; elongately oval to subcircular cardinal muscle scars, with dimensions of  $0.4 \times 0.3$  mm and  $0.7 \times 0.6$  mm in two specimens, impressed posteromedially on floor of valve symmetrically on either side of median septum and diverging anteriorly from beneath pseudointerarea at  $50^\circ$  with median axis of valve; anterior and anterolateral margins of muscle scars may be defined by elevated, thickened, crescentic ridges of shell.

**HOLOTYPE.** Complete pedicle valve, BB 95377: length 1.2 mm, width 1.4 mm. Fig. 24.

**PARATYPES.** Conjoined valves, BB 95419a, b (length 1.1 mm, width 1.5 mm); incomplete pedicle valve, BB 95418; brachial valve, BB 95378 (length 1.0 mm, width 1.2 mm).

**TYPE HORIZON AND LOCALITY.** Loc. 1.

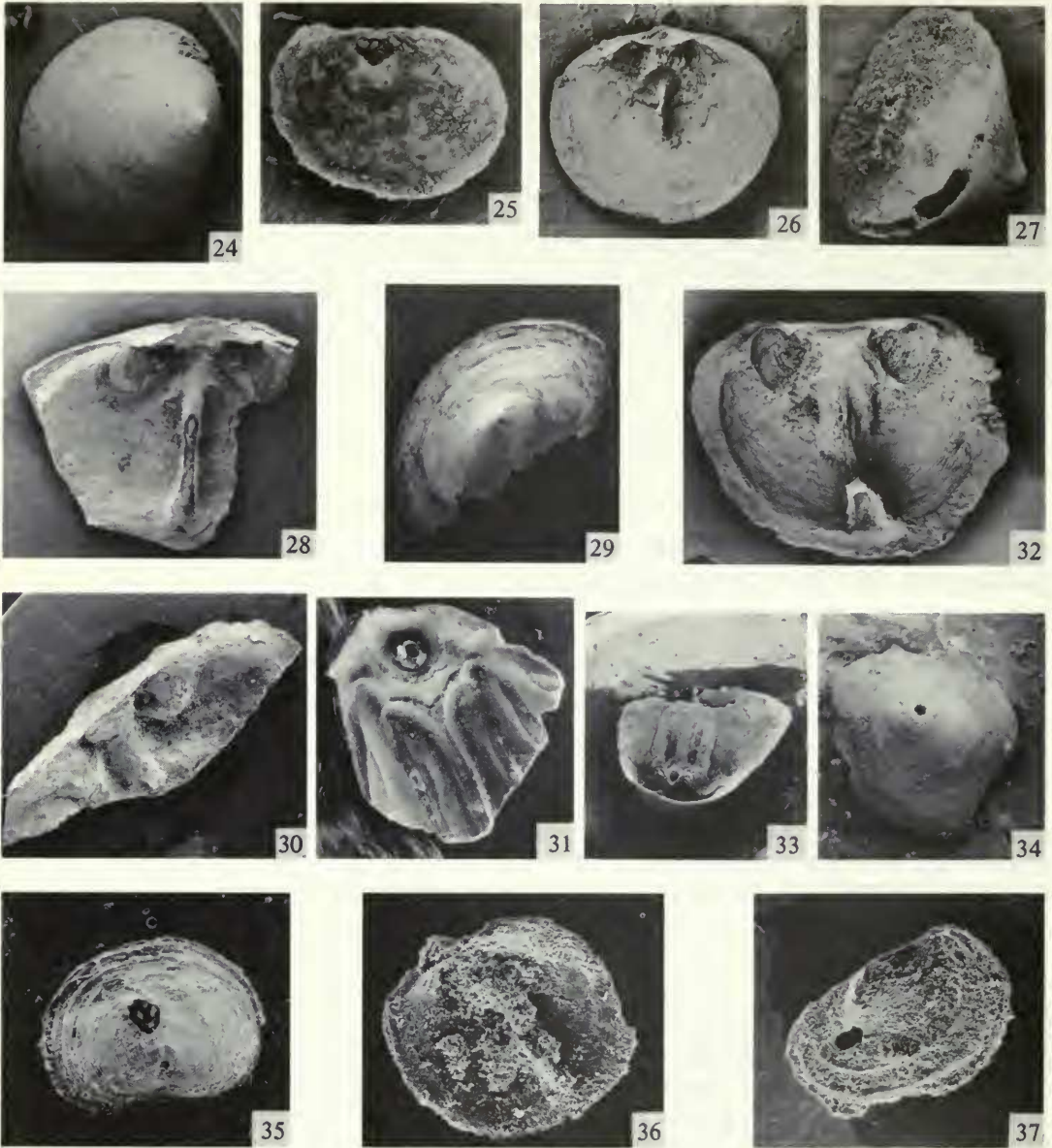
**DISCUSSION.** Almost 30 well-preserved acrotretid valves, including conjoined pairs, which have been recovered from the Tourmakeady Limestone, are assigned to *Conotreta*. The short, simple, blade-like median septum and strong posteromedially-situated cardinal muscle scars in the brachial valve, and the moderately conical pedicle valve with a prominent apical process, are diagnostic of *Conotreta*. Several authors have commented on the fact that this genus may be a junior synonym of *Acrotreta* (e.g. Cooper 1956: 248, Biernat 1973: 67). The type material of the latter genus has been lost, however, and its internal structure is unknown; it therefore seems wiser to follow the convention adopted by other workers and assign the Tourmakeady material to *Conotreta* until such time as topotypic *Acrotreta* material can be examined.

Of published older Ordovician species of *Conotreta* from North America, *C. lepton* is close to *C. multisinuata* Cooper (1956: 253) from deposits in Virginia, Alabama and Tennessee, but can readily be distinguished because the latter species has a sulcate brachial valve, and strongly impressed mantle canals in the pedicle valve. Both *C. apicalis* Cooper (1956: 249) from the Pratt Ferry Formation of Alabama, and *C. magna* Cooper (1956: 252) from the Whitesburg Formation of Tennessee, are considerably larger than *C. lepton*, and also differ in having a much more highly conical pedicle valve. *C. apicalis monstrata* from the Ordovician of Kazakhstan (Popov 1980: 89) differs from *C. lepton* in having a much more highly conical pedicle valve, a proportionately larger median septum, and more strongly developed concentric ornamentation.

*C. mica* Goryanskiĭ from the Ordovician of the Russian Platform (Goryanskiĭ 1969: 64) and north-east Poland (Biernat 1973: 67) differs from *C. lepton* in having a narrower dorsal pseudointerarea with a straight anterior margin, and a proportionately longer dorsal median septum. These two criteria also serve to distinguish *C. lepton* from *C. mica?* from the Ordovician Antelope Valley Limestone of southern Nevada (Krause & Rowell 1975: 38).

When compared with the majority of described species of *Conotreta*, *C. lepton* stands out as being uniformly smaller and exceptionally thin-shelled. Both of these features can sometimes be considered indicative of juvenile growth stages, as indeed can the absence of mantle canal impressions. But all other internal features considered characteristic of adult *Conotreta* are readily apparent in the Tourmakeady specimens, and therefore there is no basis for assuming that the sample consists solely of juveniles.





**Figs 24–27** *Conotreta lepton* sp. nov. Fig. 24, holotype BB 95377, exterior of pedicle valve,  $\times 28$ ; Fig. 25, paratype BB 95418, interior of incomplete pedicle valve,  $\times 28$ ; Fig. 26, paratype BB 95378, interior of brachial valve,  $\times 28$ ; Fig. 27, paratype BB 95419a, b, conjoined valves,  $\times 28$ .

**Figs 28–31** *Conotreta* sp. Fig. 28, BB 95424, interior of incomplete brachial valve,  $\times 8$ ; Fig. 29, BB 95425, exterior of incomplete pedicle valve,  $\times 8$ ; Fig. 30, BB 95426, interior of incomplete brachial valve,  $\times 7$ ; Fig. 31, BB 95427, interior of incomplete pedicle valve,  $\times 18$ .

**Figs 32–34** *Ceratreta dilatata* sp. nov. Fig. 32, holotype BB 95447, interior of brachial valve,  $\times 16$ ; Fig. 33, paratype BB 95448, interior of incomplete pedicle valve,  $\times 11$ ; Fig. 34, paratype BB 95449, exterior of incomplete pedicle valve,  $\times 11$ .

**Figs 35–37** *Scaphelasma* cf. *septatum* Cooper. Fig. 35, BB 95428, conjoined valves,  $\times 19$ ; Fig. 36, BB 95429, interior of brachial valve,  $\times 31$ ; Fig. 37, BB 95430, exterior of brachial valve,  $\times 22$ .



*Conotreta* sp.

Figs 28–31

**DIAGNOSIS.** Large, thick-shelled, transversely elliptical *Conotreta* about half as long as wide; pedicle valve moderately conical with apex situated at about 50% of valve length; brachial valve gently convex, with simple blade-like median septum extending about seven-tenths of valve length.

**DESCRIPTION.** Large, thick-shelled, transversely elliptical *Conotreta*, estimated to have attained a maximum length and width of approximately 5 mm and 9 mm respectively, with smoothly and gently rounded anterior and posterior margins, and narrowly rounded lateral margins; external surfaces ornamented by fine concentric fila numbering 30 per mm at 1 mm anteromedially of posterior margin of brachial valve; pedicle valve narrowly conical in lateral profile, broadly conical in anterior profile, with minute, sharply tapering umbo situated at mid-point of valve; pedicle foramen minute, circular, about 0.15 mm in diameter, and situated apically; pseudointerarea of pedicle valve poorly to moderately well defined, smoothly rounded or slightly flattened, and undivided; interior of pedicle valve with strongly thickened apical process along anterior slope of valve forming anterior margin of enlarged, subcircular, pedicle tube; anterior slope of pedicle valve with strongly developed pinnate mantle canal system defined by at least six narrow, elevated, parallel-sided to subtriangular ridges, 0.1–0.2 mm wide and with a maximum height of 0.2 mm dorsomedially, radiating anteriorly and anterolaterally from apical process; branches of mantle canals averaging 0.4 mm in width (range 0.3–0.5 mm) in one specimen; pair of small, subcircular to elongately oval cardinal (?) muscle pits impressed on anterolateral margin of apical process and thickened valve floor.

Brachial valve gently convex posteromedially, becoming flattened posterolaterally; dorsal umbo rounded, low, poorly defined, extended posteriorly of posterior margin of valve for a short distance; interior of brachial valve with narrow, anacline, adnate, pseudointerarea with sunken median plate, 1.4 mm wide × 0.5 mm long in one specimen, separating poorly-defined, narrowly triangular propleas; posteromedian margin of pseudointerarea buttressed to thickened valve floor by rounded boss of shell, which may be extended anterolaterally as pair of short, rounded processes; floor of valve with low, blade-like, median septum with thickened, rounded, rod of shell developed along its posterior slope and extending anterodorsally beyond apex of median septum as rounded, erect, boss of shell; median septum estimated to have extended anteriorly for about 70% of maximum valve length, with the apex situated at about 50% of its maximum length; paired subtriangular to elongately oval cardinal muscle scars, 1.0 mm long × 0.6 mm wide in one specimen, impressed posterolaterally on elevated, thickened boss of shell strongly grooved by growth-lines, and diverging anteriorly at 60° to median axis of valve.

**FIGURED MATERIAL.** Incomplete pedicle valves, BB 95425 (width 4.0 mm), 95427; incomplete brachial valves, BB 95424, 95426. Loc. 1.

**DISCUSSION.** Although fragmentary, it is clear that the Tourmakeady fauna included one of the largest representatives of *Conotreta* yet described, matched in size only by *C. gigantea* Cooper (1956: 251), from the Pratt Ferry Formation of Alabama, and *C. magna* Cooper (1956: 252), from the Whitesburg Formation of Tennessee. The two American species can readily be distinguished from the Tourmakeady specimens, however, as both have a narrowly conical pedicle valve with a posteriorly situated apex, and a well-defined, medially divided, ventral pseudointerarea. The strongly transversely-oval outline also serves to distinguish the Irish material from the circular to slightly transversely-oval American species.

*C. apicalis monstrata* Popov (1980: 88), from the Ordovician of Kazakhstan, differs from the Irish specimens in having a much wider dorsal pseudointerarea, an almost straight posterior margin, and stronger external ornamentation. However, although the Irish specimens are distinctive, specific recognition has been withheld in view of the sparseness of the available sample.

## Subfamily CERATRETINAE Rowell, 1965

## Genus CERATRETA Bell, 1941

*Ceratreta dilatata* sp. nov.

Figs 32–34

DIAGNOSIS. Transversely oval *Ceratreta*, about four-fifths as long as wide; brachial valve interior with long, low, median septum bifurcating anteriorly to form arch-like process and flanked posteriorly by broad, low, flattened platform.

NAME. 'Swollen'.

DESCRIPTION. Medium-sized, transversely oval *Ceratreta*, 85% as long as wide in one specimen, with strongly rounded lateral and anterior margins and almost straight posterior margin; external surfaces ornamented by fine concentric fila numbering 18 per mm in the median region of the brachial valve.

Pedicle valve strongly conical in lateral profile, with sharply tapering, rounded apex situated posteriorly of posterior margin of valve; ventral pseudointerarea procline, flattened, triangular, subdivided medially by faint, broad intertrough; pedicle foramen minute, elongately oval, 0.1 mm long  $\times$  0.05 mm wide in one specimen, situated posteriorly of apex along posterior slope of valve.

Interior of pedicle valve with well-developed apical process as swollen boss, extended medially along inner wall of ventral pseudointerarea as rounded, elevated ridge bounding circular internal pedicle opening; two narrow branches of bacculate mantle canal system impressed symmetrically on either side of apical process along inner wall of ventral pseudointerarea.

Brachial valve gently convex in lateral profile, with prominent rounded umbo extending posteriorly beyond posterior margin of valve; brachial valve interior with well-defined, concave, apsacline, triangular pseudointerarea, undivided medially, and with a straight anterior margin buttressed medially to floor of valve by broad, thickened, boss of shell; floor of brachial valve with long, low, thickened median septum extending almost to flattened anterior margin of valve; anterior margin of median septum elevated medially and bifurcating to form narrow, incurved, anterolateral lobes disposed as an arch-like process; median septum flanked posteriorly by broad, low, thickened, platform extending for about half of valve length; strong, subtriangular cardinal muscle scars, measuring 0.5 mm  $\times$  0.4 mm in one specimen, impressed posterolaterally on valve floor, and diverging anteriorly at 60° to median axis of valve.

HOLOTYPE. Complete brachial valve, BB 95447: length 2.2 mm, width 2.6 mm. Fig. 32.

PARATYPES. Incomplete pedicle valves, BB 95448, 95449.

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. The Tourmakeady specimens are undoubtedly representatives of the rare acrotretid genus *Ceratreta*, which is known primarily from Upper Cambrian deposits in the U.S.A. (Bell 1941). Features such as an elongate apical process in the pedicle valve, a well-developed undivided dorsal pseudointerarea, and a long dorsal median septum elevated anteriorly, are diagnostic of this genus.

*C. dilatata* is readily distinguished from *C. hebes*, the type species of the genus from the Upper Cambrian of North America (Bell 1941: 233), as the latter has a bluntly conical pedicle valve, and lacks anterolateral lobes on the dorsal median septum. In addition, the flattened platform flanking the median septum is unique to *C. dilatata*.

Subfamily SCAPHELASMATINAE Rowell, 1966

Genus SCAPHELASMA Cooper, 1956

*Scaphelasma* cf. *septatum* Cooper

Figs 35–37

cf. 1956 *Scaphelasma septatum* Cooper: 260.

The etched residues of the Tourmakeady Limestone, recovered from Loc. 1, contained a small number of minute, well-preserved, complete valves, which are undoubtedly representatives of the distinctive acrotretid genus *Scaphelasma*. The specimens, one conjoined pair (BB 95428) and three brachial valves (BB 95429–30, BB 95517), are transversely oval in outline, averaging 76% (range 69–86%) as long as wide in 3 specimens, with smoothly rounded anterior and lateral margins and a straight posterior margin. The valves are ornamented by concentric growth-lines which become strongly lamellose peripherally. The pedicle valve is moderately conical in lateral profile being 46% as high as wide, and has a strongly rounded, posteriorly situated, umbo. The narrowly triangular, procline ventral pseudointerarea is subdivided medially by a well-developed intertrough which is very narrow ventrally but becomes wider dorsally. The brachial valve is convex posteromedially, with a prominent, rounded umbo projecting posteriorly of the posterior margin of the valve. The margins of the brachial valve are flattened or slightly concave. On the interior of the brachial valve the dorsal pseudointerarea is narrow and undivided. A short, triangular, median septum arises at about the midpoint of the valve and extends anteriorly almost to the anterior margin of the valve.

A comparison between the Tourmakeady specimens and *S. septatum* Cooper (1956: 260), the type species of *Scaphelasma* from the Middle Ordovician Pratt Ferry formation of Alabama, indicates that no valid morphological criteria exist to justify the erection of a new species. The size and proportions of valves from the Irish and American localities are very similar. Thus, the holotype of *S. septatum*, a pedicle valve, is 78% as long as wide and 43% as high as wide, while the comparable proportions for the sole pedicle valve (BB 95428) in the Tourmakeady sample are 69% and 46% respectively. Some slight differences were detected, however; notably fewer concentric lamellae and a proportionately wider ventral pseudointerarea on the Tourmakeady specimen. In addition, the characteristic pattern of large and small pits on the protegular surface are consistently larger in the Irish valves, averaging 3.85  $\mu\text{m}$  (range 3.6–4.2  $\mu\text{m}$ ) and 430 nm (range 300–500 nm) for larger and smaller pits respectively, as compared with a maximum of 3.0  $\mu\text{m}$  and 300 nm recorded by Biernat & Williams (1970: 494) for topotypic *S. septatum*.

## Subfamily TORYNELASMATINAE Rowell, 1966

Genus *MYLLOCONOTRETA* nov.

DIAGNOSIS. Small, transversely to elongately oval acrotretid, with juvenile pedicle and brachial valves moderately conical and gently convex or plane respectively, adult valves strongly geniculate anteriorly and anterolaterally; external surfaces ornamented by fine concentric fila which are wavy, discontinuous, narrowly tapering distally and occasionally nodose during early growth stages, but becoming evenly-spaced and smoothly rounded distally on post-geniculation valve surfaces.

Pedicle valve with minute, transversely oval, smooth protegulum, ventral pseudointerarea broadly triangular, procline, and undivided.

Brachial valve with narrow, anacline, undivided pseudointerarea; median septum large, blade-like, extending to anterior margin of valve and surmounted by concave, bilobed, plate; strong, elevated, cardinal muscle platforms developed posterolaterally on valve floor.

NAME. Greek,  $\mu\upsilon\lambda\lambda\acute{o}\varsigma$ , crooked.

TYPE SPECIES. *Myloconotreta elimata* sp. nov., from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The conical pedicle valve with its minute apical foramen and the strong dorsal



median septum are features which immediately establish the new genus as a representative of the Acrotretidae. Furthermore, its inclusion within the *Torynelasmatinae* is equally justifiable, as the concave surmounting plate on the dorsal median septum is diagnostic of that subfamily.

The strong geniculation in both valves associated with the change in external ornamentation are features which have not previously been recorded in any *torynelasmatinid*, and therefore serve to distinguish *Myloconotreta* from other genera assigned to this small subfamily. Apart from lacking geniculation, *Torynelasma* Cooper also differs in having an apsacline rather than a procline ventral pseudointerarea and a strongly conical protegulum, usually with well-developed external pitting. The taxonomic significance of this latter feature has not been established, but the additional difference in the shape of the ventral protegulum indicates differences in growth during early life.

The new genus is known at present only from the Tourmakeady Limestone.

*Myloconotreta elimata* sp. nov.

Figs 38–44

**DIAGNOSIS.** Small, moderately to strongly transversely oval *Myloconotreta*, averaging seven-tenths as long as wide, with straight posterior margin, strongly rounded lateral margins, and smoothly and gently rounded anterior margins; external surfaces ornamented by fine concentric fila numbering about 15 per  $100\mu\text{m}$  at 1 mm anteriorly of ventral umbo; interior of brachial valve with strong triangular median septum surmounted by concave, heart-shaped plate.

**NAME.** 'Made smooth'.

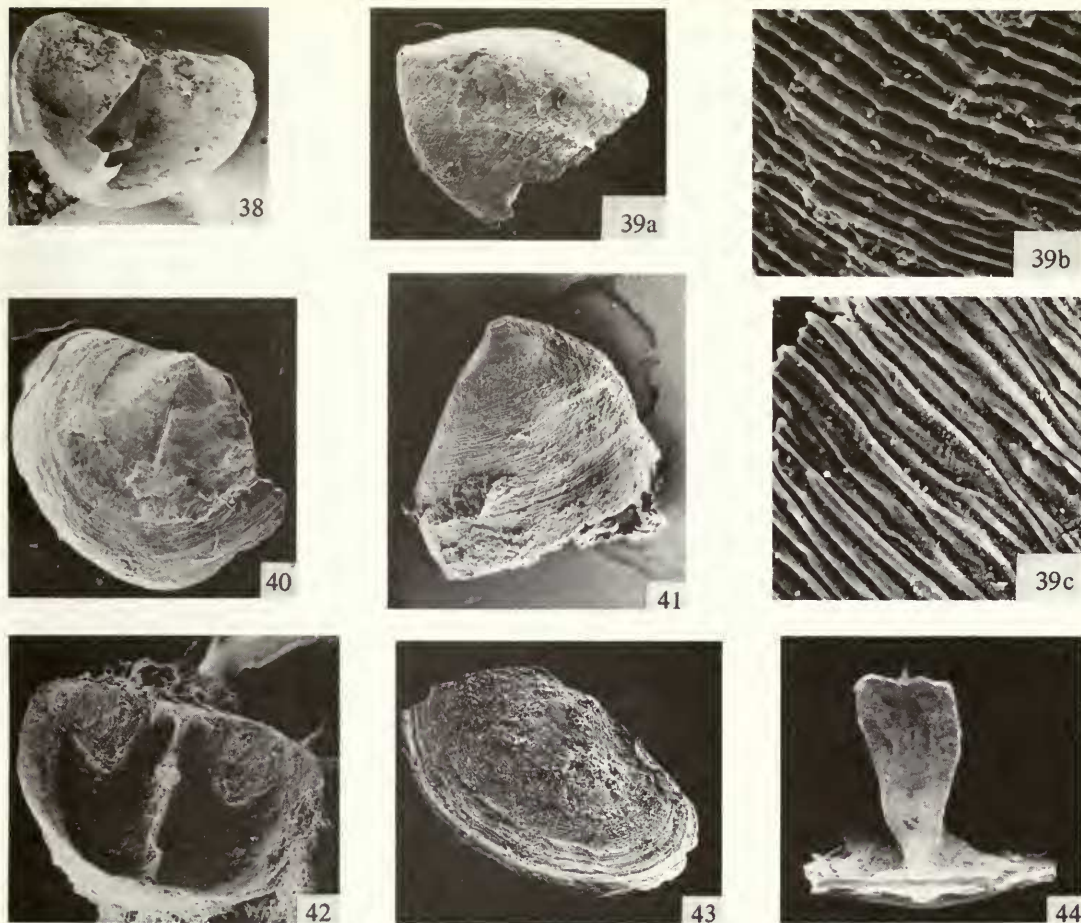
**DESCRIPTION.** Small, moderately to strongly transversely oval *Myloconotreta*, on average 69% as long as wide ( $\bar{l}$  mm (var l) 1.19 (0.06),  $\bar{w}$  mm (var w) 1.71 (0.07),  $r = 0.815$ ;  $n = 7$  brachial valves) with straight posterior margin, strongly rounded lateral margins, and smoothly and gently rounded anterior margins; external surfaces ornamented by fine concentric fila with wavelength and amplitude averaging  $7\mu\text{m}$  and  $4\mu\text{m}$  respectively over the entire valve surface; fila discontinuously developed, irregularly undulating, wavy, and narrowly tapering distally on juvenile valve surfaces, but changing abruptly at zone of geniculation to become evenly spaced, and smoothly rounded on post-geniculation valve surfaces.

Pedicle valve moderately conical in lateral profile, with strong geniculation along lateral and anterolateral margins, developed at an average distance of 0.6 mm (range 0.4–0.7 mm in 5 specimens) from ventral apex along anterior slope of valve; geniculate zone directed dorsally so that adult valve appears as a parallel-sided, cylindrical tube distally, surmounted proximally by triangular juvenile cone; ventral beak situated slightly posteriorly of mid-point of valve; pedicle foramen minute, circular, with a diameter of about  $140 \times 110\mu\text{m}$  in one specimen; external surfaces of protegulum smooth; ventral pseudointerarea broadly triangular, procline, flattened, and undivided.

Brachial valve gently convex to plane in lateral profile when juvenile, becoming strongly and sharply geniculate anteriorly and anterolaterally in later growth stages, with a maximum thickness anteromedially of up to 67% of valve length (average 45%; range 23–67% in 6 specimens); angle of geniculation variable, ranging from  $30^\circ$  to more than  $90^\circ$ ; external surfaces of brachial valves with variably-developed median sulcus, very narrow in juveniles, becoming broader and moderately rounded anteriorly.

Dorsal interior with narrow, anacline undivided pseudointerarea, sunken medially, elevated along its anterior margin, and buttressed medially to floor of valve by T-shaped boss of shell; floor of valve with large, blade-like, triangular median septum arising just forward of pseudointerarea and extending to anterior margin of valve in all growth stages; posterior slope of median septum with erect, concave, surmounting plate, very narrow dorsally but





**Figs 38–44** *Mylloconotreta elimata* gen. et sp. nov. Fig. 38, holotype BB 95420, interior of brachial valve,  $\times 16$ ; Fig. 39a, b, c, paratype BB 95421: a, exterior of incomplete pedicle valve,  $\times 21$ ; b, c details of ornamentation, both  $\times 200$ ; Fig. 40, paratype BB 95422, oblique view of exterior of incomplete brachial valve,  $\times 24$ ; Fig. 41, paratype BB 95423, lateral view of exterior of incomplete pedicle valve,  $\times 14$ ; Fig. 42, paratype BB 95355, interior of brachial valve,  $\times 14$ ; Fig. 43, paratype BB 95354, oblique view of exterior of incomplete brachial valve,  $\times 25$ ; Fig. 44, paratype BB 95357, posterior view of incomplete brachial valve,  $\times 31$ .

widening progressively ventrally and extending beyond ventral apex of median septum as pair of symmetrically-disposed, rounded lobes reaching 81% and 78% as high as valve length in two specimens; strong, elevated, cardinal muscle platforms, triangular to tear-shaped in outline and averaging 73% as long as wide ( $\bar{l}_{sc}$  mm (var l) 0.40 (0.006),  $\bar{w}_{sc}$  mm (var w) 0.29 (0.001),  $r = 0.789$ ;  $n = 7$ ), developed posterolaterally on floor of valve and diverging anteriorly at 40–50° with median axis of valve.

**HOLOTYPE.** Brachial valve, BB 95420: length 1.6 mm, width 2.1 mm. Fig. 38.

**PARATYPES.** Incomplete pedicle valves, BB 95421, 95423, 95354 (length 1.0 mm); brachial valve, BB 95355 (length 1.2 mm, width 1.6 mm); incomplete brachial valves, BB 95422 (length 1.3 mm), 95357.

**TYPE HORIZON AND LOCALITY.** Loc. 1.

*Myloconotreta* sp.

Figs 45–46

Specimens assigned to *Myloconotreta elimata*, above, show the sort of variation expected of a morphologically homogeneous species. However, the Tourmakeady residues have also yielded a small number of congeneric valves which may be a separate stock. These valves (BB 95431–95434) are immediately distinguishable in being strongly elongately oval, although in the nature of the ornamentation and form of dorsal median septum they are similar to *Myloconotreta*. The sample is too small to preclude attribution of differences in outline to sexual dimorphism, distortion, or even an indication of high intraspecific variability. Among these elongately oval specimens are a few strongly geniculate pedicle valves which certainly belong to the new genus, although none of the matching brachial valves shows the strong geniculation which would be expected in similarly-sized specimens of *M. elimata*. A close examination of the anteromedian margin of these brachial valves does reveal a slight ventrally-directed deflection in the growth direction, which may indicate incipient geniculation. In all probability, therefore, these valves are not fully mature.

The taxonomic status of these elongately oval shells can only be resolved when a much larger sample is available for study; until more material has been obtained, specific identification is withheld.

## ? Superfamily ACROTRETACEA Schuchert, 1893

## Family EOCONULIDAE Rowell, 1965

## Genus EOCONULUS Cooper, 1956

*Eoconulus* sp.

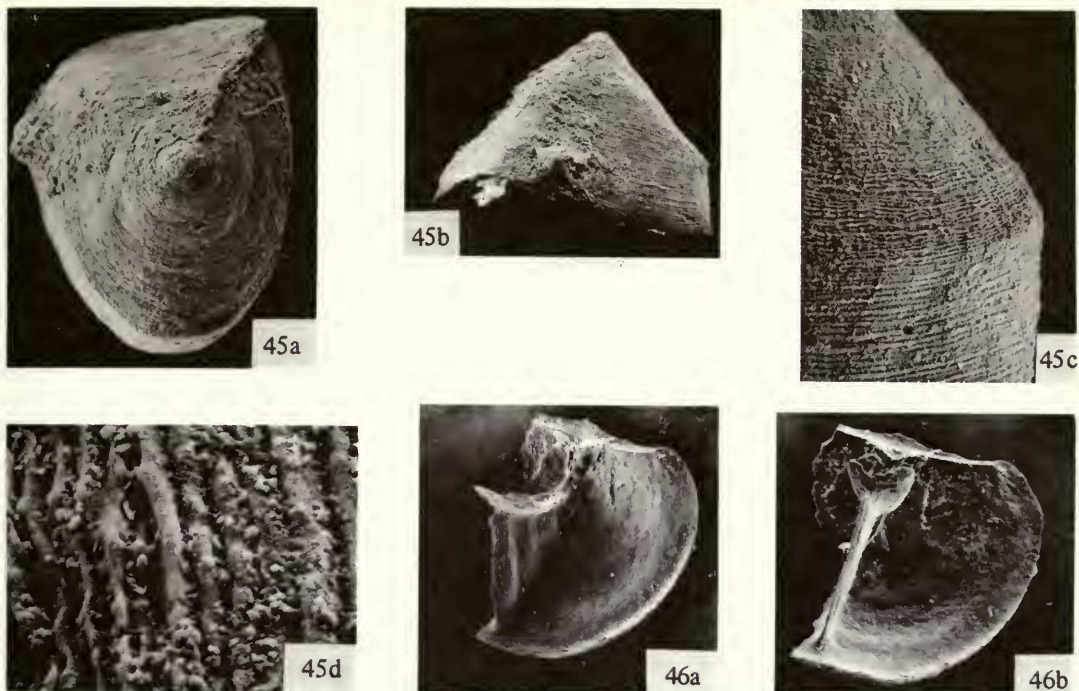
Fig. 47

The etched residues of Tourmakeady Limestone exposed at Loc. 1 yielded a single example of the enigmatic genus *Eoconulus*. The specimen (BB 95440), which is thought to be an incomplete pedicle valve, is subquadrate in outline, and is estimated to have been 0.8 mm long and 1.0 mm wide when complete. In lateral profile the valve is an imperfect cone, with a large, flattened, subcircular apex situated posteriorly. The external surface is ornamented by fine discontinuous fila numbering about 15 per mm over the anterior slope of the valve. Internally a prominent, rounded process is developed at the posteromedian margin of a thickened apical region. The median process is flanked by relatively large, deep, pits.

*Eoconulus* is an unusual genus, and when first described was known only from its brachial valve (Cooper 1956: 282). Subsequently, however, Krause & Rowell (1975: 64) recovered conjoined pedicle and brachial valves from the Lower Ordovician Antelope Valley Limestone of southern Nevada. Prior to this discovery it had been assumed that *Eoconulus* lived attached to the substrate by a pedicle valve which was not preserved because it was unmineralized. Having recovered mineralized pedicle valves with prominent attachment scars, Krause & Rowell emended the diagnosis of the genus to read 'cemented by a pedicle valve which may or may not be mineralised'. The work of Krause & Rowell on the Nevada species indicates that the pedicle and brachial valves of *Eoconulus* are externally similar, both being moderately conical in lateral profile. Internally, however, they are readily distinguishable, as the pedicle valve has a prominent apical process. If this feature is assumed to be characteristic, then the prominent internal process in the Tourmakeady specimen immediately identifies it as a pedicle valve. With only a single, incomplete, specimen available for study a detailed comparison with previously described species of *Eoconulus* is clearly impracticable. However, it is interesting that the sole representative of the genus in the Tourmakeady fauna appears to be a pedicle valve; most commonly only brachial valves are recovered (Cooper 1956: 282, Biernat 1973: 111).

The taxonomic affinities of *Eoconulus* are problematical. Originally it was decided that the





**Figs 45–46** *Myloconotreta* sp. Fig. 45a, b, c, d, BB 95431, pedicle valve: a, ventral view,  $\times 22$ ; b, lateral view,  $\times 17$ ; c, enlarged lateral view,  $\times 54$ ; d, ornamentation,  $\times 420$ . Fig. 46a, b, BB 95432, incomplete brachial valve: a, oblique lateral view; b, anterior view; both  $\times 25$ .

genus was most appropriately incorporated within the Craniacea because of its attached mode of life (Cooper 1956: 282). The subsequent discovery of a mineralized conical pedicle valve with a prominent apical process led Krause & Rowell to assign *Eoconulus* to the Acrotretacea, albeit tentatively. Biernat (1963: 111) had also considered this latter possibility, but had rejected it because the pattern of protegular pits seen on *Eoconulus* differs from that seen on most acrotretaceans (Biernat & Williams 1970: 499). However, the taxonomic significance of differences in protegular surface sculpture has not been ascertained, and pits are indeed absent from some undoubted acrotretaceans, such as *Myloconotreta* gen. nov. from the Tourmakeady Limestone (p. 203). Therefore, it seems more appropriate to follow the procedure adopted by Krause & Rowell, while acknowledging that the genus is at best only tentatively assigned to the Acrotretacea.

Superfamily **DISCINACEA** Gray, 1840

Family **DISCINIDAE** Gray, 1840

Subfamily **ORBICULOIDEINAE** Schuchert & LeVene, 1929

Genus **SCHIZOTRETA** Kutorga, 1848

*Schizotreta* sp.

Figs 48–49

The residues from the Tourmakeady Limestone exposed at Loc. 1 contained one almost complete brachial valve (BB 95408), and several similarly-ornamented fragments (BB



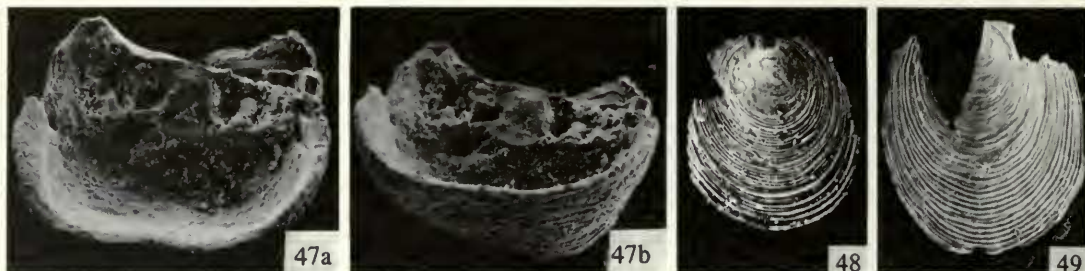


Fig. 47a, b *Eoconulus* sp. BB 95440, interior and oblique anterior views of incomplete pedicle valve, both  $\times 42$ .

Figs 48–49 *Schizotreta* sp. Fig. 48, BB 95408, exterior of brachial valve,  $\times 9$ ; Fig. 49, BB 95518, exterior of incomplete brachial(?) valve,  $\times 11$ .

95518), attributable to *Schizotreta*, especially on account of its submarginal beak (Krause & Rowell 1975: 69). A reconstruction indicates that the brachial valve was about 3 mm long and 2.5 mm wide when complete, and was elongately oval in outline with strongly and smoothly rounded anterior and lateral margins. The valve has a low conical lateral profile, 14% as high as long, with the apex situated about 0.5 mm anterior of the posterior margin. Anteriorly and anterolaterally the valve becomes almost flat. The external surfaces of all specimens are ornamented by fine, elevated, evenly-spaced, concentric fila numbering 16 per mm about 1 mm anterior of the beak. The rounded, submarginal beak of the brachial valve is separated from the posterior margin of the valve by a low, broadly triangular, hypercline pseudointerarea.

In shape and form of external ornamentation the Tourmakeady specimens are similar to congeneric species recovered from Lower and Middle Ordovician sediments from North America (Cooper 1956: 277; Krause & Rowell 1975: 69). The majority of American specimens are, however, considerably larger than the Irish ones, which are very thin-shelled and may well be juveniles. Even so, *Schizotreta* sp. from the Antelope Valley Limestone (Krause & Rowell 1975: 69) does have dimensions similar to those of the Irish specimens, although the latter are readily distinguishable in having finer and more numerous concentric fila. The inadequate sample available for study makes detailed comparisons with other described *Schizotreta* unprofitable, and specific identification impossible.

#### Superfamily SIPHONOTRETACEA Kutorga, 1848

#### Family SIPHONOTRETIDAE Kutorga, 1848

#### Genus *CYRBASIOTRETA* nov.

DIAGNOSIS. Transversely oval siphonotretacean with conical pedicle valve and gently convex sulcate brachial valve, ornamented by increasingly strong lamellae each bearing a single row of fine, evenly-spaced, hollow spines; oval pedicle foramen tapering sharply posteriorly to small, triangular beak projecting posteriorly over large, procline, ventral pseudointerarea divided medially by faint median ridge forming pedicle trail; posterior margin of pedicle foramen closed by small concave plate; brachial valve with narrow, undivided pseudointerarea.

NAME. Greek, *κυρβάσιον*, a Persian hat.

TYPE SPECIES. *Cyrbasiotreta cirrata* sp. nov., from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The most distinctive feature of the new genus is its strongly conical pedicle valve, which has not been recorded previously in any siphonotretacean genus. Yet there is no doubt that *Cyrbasiotreta* is most appropriately assigned to the Siphonotretacea, as is indicated by other basic features like its hollow external spines, the well-developed pedicle

trail and rudimentary dorsal pseudointerarea. Indeed the brachial valve of *Cyrbasiotreta* could, at first sight, be confused with that of *Schizambon* Walcott or *Multispinula* Rowell. *Cyrbasiotreta* can readily be distinguished from the former, however, which has a gently convex pedicle valve with a marginal beak. *Schizambon* also lacks a well-developed ventral pseudointerarea and has irregularly-distributed spines, while the plate closing the posterior margin of the pedicle foramen is adnate with the posterior margin of the valve.

The ventral pseudointerarea of *Multispinula* is much narrower than that of *Cyrbasiotreta*, and the pedicle foramen is proportionately much larger. Internally the two genera differ markedly in that the pedicle of *Multispinula* was encased within a tube.

In addition to its distinctive conical pedicle valve, there are other morphological features of *Cyrbasiotreta* which serve to distinguish it from other siphonotretacean genera. The nature of its external ornamentation and the form of the pedicle foramen are especially useful. These two features, for example, distinguish *Cyrbasiotreta* from *Karnotreta* (p. 211), the other new siphonotretacean genus from Tourmakeady, which has spines formed by the folding of lamellae and a pedicle tube ankylosed posteromedially with the inner wall of the ventral pseudointerarea. Indeed the absence of a pedicle tube internally excludes *Cyrbasiotreta* from the newly-erected subfamily Schizamboninae Havlíček (1982). *Siphonotreta* de Verneuil differs in having a well-developed pedicle tube and a strongly apsacline ventral pseudointerarea, and in being sparsely and irregularly spinose. *Helmersenina* Pander, with its sealed pedicle foramen in adult valves, can also be readily distinguished from *Cyrbasiotreta*, as can *Dysoristus* Bell which lacks external spines, and *Alichova* Goryanskii which bears scattered branching spines.

The morphology of *Cyrbasiotreta* is of interest in the context of the evolutionary history of the Siphonotretacea. The origins of the group are not known with certainty, but it has been suggested, on the basis of a similarity in the structure of the dorsal posterior margin, that the acrotretaceans provided the ancestral stock (Rowell 1962: 151). Clearly the discovery of a new siphonotretacean with an acrotretacean-like pedicle valve would tend to support this view.

The new genus is at present monospecific and is known only from the small sample of predominantly incomplete specimens recovered from the Tourmakeady Limestone.

### *Cyrbasiotreta cirrata* sp. nov.

Figs 50–56

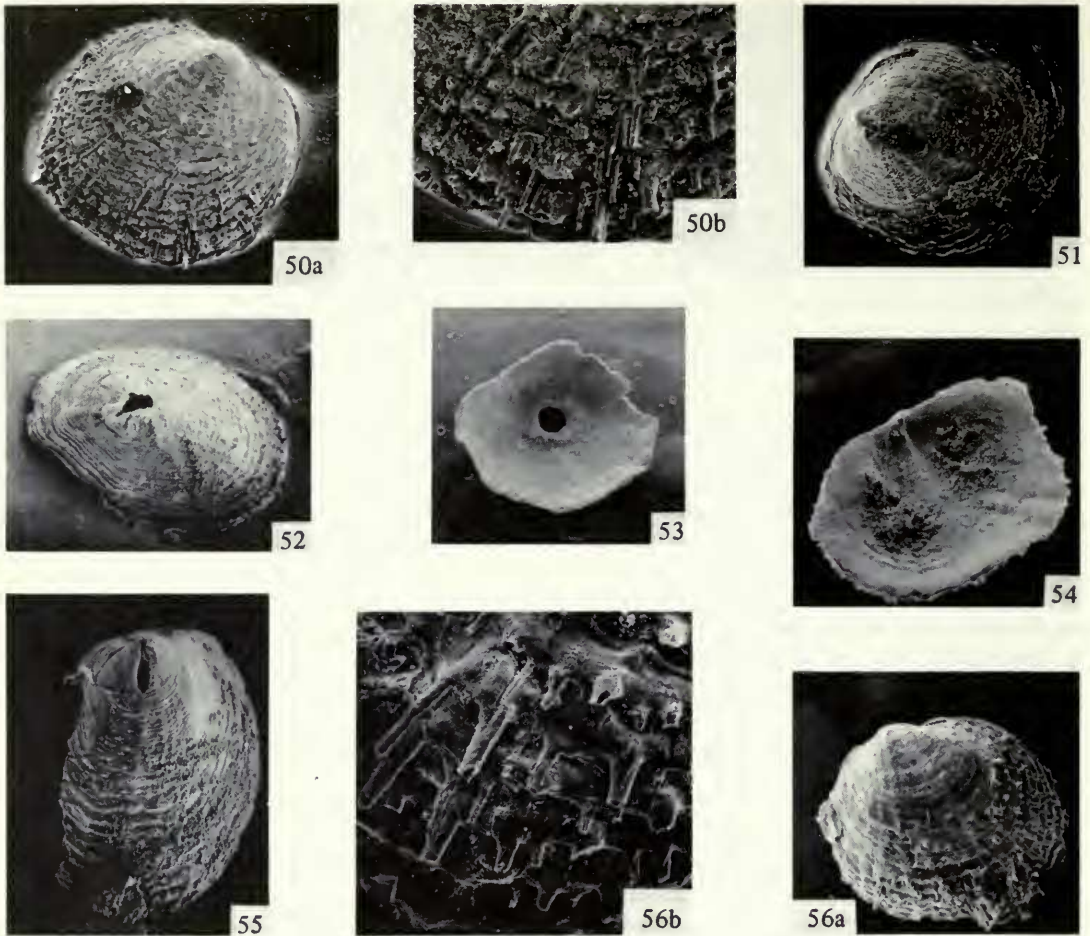
**DIAGNOSIS.** Small, moderately to strongly transversely oval *Cyrbasiotreta*, between three-fifths to nine-tenths as long as wide, with conical pedicle valve about three-fifths as high as long; pedicle foramen elongately oval, about two-fifths as wide as long and about one-sixth as long as valve; external surfaces ornamented by hollow, circular spines ranging up to 50  $\mu\text{m}$  in diameter.

**NAME.** 'Fringed'.

**DESCRIPTION.** Small, moderately to strongly transversely oval *Cyrbasiotreta*, ranging from 60% to 90% as long as wide in 4 specimens, with smoothly rounded lateral and anterior margins and almost straight posterior margin; external surfaces becoming strongly lamellose distally with each lamella bearing single row of hollow, suberect, circular, spines along anterior margin; spines with diameters ranging 10–50  $\mu\text{m}$ , and spaced at average distance of 85  $\mu\text{m}$  (range 30–125  $\mu\text{m}$ ).

Pedicle valve conical in lateral profile, 61% as high as long in one specimen, with rounded umbo situated slightly posteriorly of mid-point of valve; pedicle foramen elongately oval, averaging 43% (range 40–48%) as wide as long in 6 specimens and 17% as long as valve in one specimen, smoothly rounded anteriorly and with rounded lateral margins tapering posteriorly to small, triangular beak projecting posteriorly to overhang well-developed, triangular, flattened, procline, ventral pseudointerarea divided medially by faint ridge; posterior margin of pedicle foramen closed by small concave plate which projects through





**Figs 50–56** *Cyrbasiotreta cirrata* gen. et sp. nov. Fig. 50a, b, **holotype** BB 95436, exterior of brachial valve: a,  $\times 16$ ; b, enlargement of ornamentation,  $\times 50$ ; Fig. 51, paratype BB 95435, exterior of incomplete pedicle valve,  $\times 20$ ; Fig. 52, paratype BB 95437, oblique external view of distorted pedicle valve,  $\times 14$ ; Fig. 53, paratype BB 95439, interior of incomplete pedicle valve,  $\times 18$ ; Fig. 54, paratype BB 95438, interior of incomplete brachial valve,  $\times 17$ ; Fig. 55, paratype BB 95607, exterior of distorted pedicle valve,  $\times 17$ ; Fig. 56a, b, paratype BB 95608, exterior of brachial valve: a,  $\times 15$ ; b, enlargement of ornamentation,  $\times 75$ .

umbo to form slightly elevated posterior margin of internal pedicle opening; lateral and anterior margins of internal pedicle opening thickened in some specimens to form low rounded or flattened ridge.

Brachial valve moderately convex in lateral profile with small rounded umbo projecting slightly posteriorly beyond posterior margin of valve; dorsal median sulcus very narrow posteriorly but becoming broader and shallower anteriorly; dorsal pseudointerarea very narrow, slightly sunken medially and buttressed by narrow median boss of shell in some specimens; muscle scars unknown.

**HOLOTYPE.** Brachial valve, BB 95436: length 2.0 mm, width 2.2 mm. Fig. 50.

**PARATYPES.** Incomplete pedicle valves, BB 95435, 93439, 95607; distorted pedicle valve, BB 95437; incomplete brachial valves, BB 95438, 95608 (length 2.0 mm).

**TYPE HORIZON AND LOCALITY.** Loc. 1.



Subfamily **SCHIZAMBONINAE** Havlíček, 1982Genus **KARNOTRETA** nov.

**DIAGNOSIS.** Small, subcircular, ventribiconvex siphonotretid, with truncated posterior margins; external shell surfaces ornamented by fine concentric growth-lines becoming lamellose peripherally and bearing regular rows of flattened, hollow, prone spines; pedicle valve low, conical in lateral profile with subcircular pedicle foramen situated posteriorly; ventral pseudointerarea narrow, triangular, apsacline, divided medially by low, rounded ridge.

Ventral interior with circular, dorsally-directed pedicle tube, adnate posteromedially with inner surface of ventral pseudointerarea.

Dorsal interior with narrow, thickened, anacline pseudointerarea arched medially to form convex fold of shell; floor of valve with low median septum and elongately-oval posterolateral muscle scars diverging anteriorly.

**NAME.** Greek, *κάρνον*, a horn.

**TYPE SPECIES.** *Karnotreta adnata* sp. nov., from the Tourmakeady Limestone, Co. Mayo.

**DISCUSSION.** The new genus is represented by a small number of well-preserved specimens including complete pedicle and brachial valves. The taxonomic affinities of *Karnotreta* are not in doubt, as the combination of a low conical pedicle valve with a circular pedicle foramen extended into the valve interior as a tube, and the spinose external surfaces, are characteristic of the siphonotretids. Indeed, when compared with other genera at present assigned to the family, it is apparent that the features which characterize *Karnotreta* have been recorded previously, but it is their appearance in a single taxon which justifies the erection of a new genus. Thus *Multispinula* Rowell, its closest morphological comparison, resembles *Karnotreta* in having regularly-arranged rows of spines and a pedicle tube, but differs in that the spines are circular and the pedicle tube is directed anterodorsally and is not adnate with the inner wall of the ventral pseudointerarea. *Multispinula* is, in addition, much larger than *Karnotreta*, as is *Siphonotreta* de Verneuil, which can be further distinguished on the basis of a wide, strongly apsacline, ventral pseudointerarea and a proportionately smaller pedicle foramen extending through a greatly thickened ventral umbo.

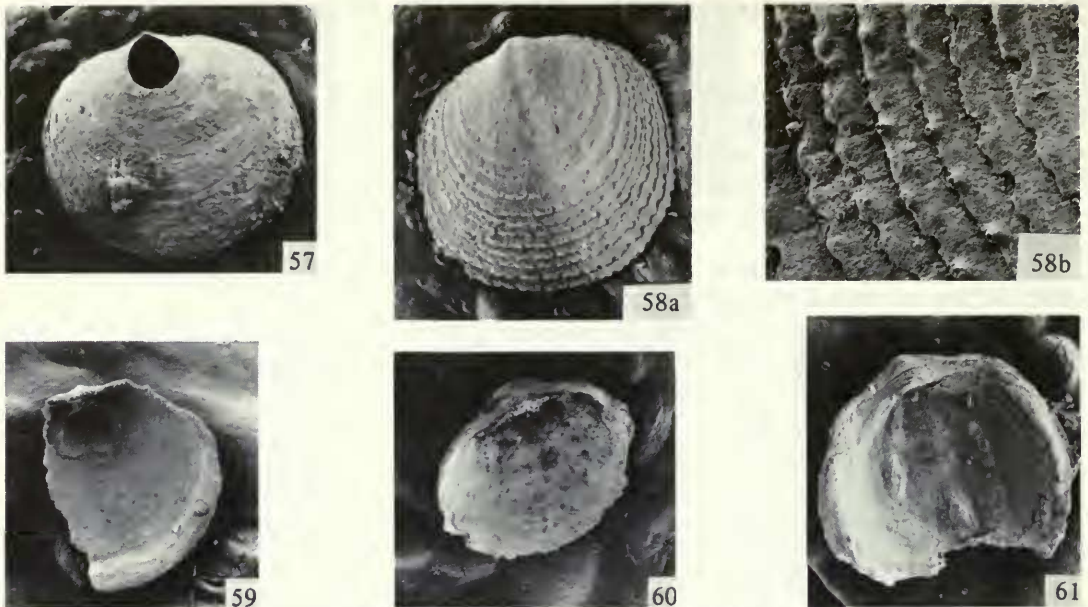
*Schizambon* Walcott differs from *Karnotreta* in lacking a well-developed ventral pseudointerarea, and in having external valve surfaces covered with fine spines. *Dysoristus* Bell can immediately be distinguished from the new genus as it lacks spines, and has an internal pedicle tube free of the ventral pseudointerarea. Similarly, *Helmerseniania* Pander would not readily be confused with the new genus, as it has a narrow ventral pseudointerarea and scattered external spines. Differences in shell shape and ornamentation, and in the form of the brachial pseudointerarea, are the primary features distinguishing between *Karnotreta* and the poorly-known genus *Alichova* Goryanskii. The latter differs at least in having distinctive, widely-spaced, erect, branching spines, a narrower dorsal pseudointerarea, and an elongately-oval shape.

At present *Karnotreta* is monospecific, and known only from the Tourmakeady Limestone. However, the form of the external spines on the new genus is distinctive; it is possible that a re-examination of previously unidentifiable spinose valves from Ordovician or Upper Cambrian successions will show *Karnotreta* to have been more widespread.

*Karnotreta adnata* sp. nov.

Figs 57-61

**DIAGNOSIS.** Thin-shelled, subcircular, *Karnotreta*, about nine-tenths as long as wide; pedicle valve low, conical, about one-third as high as long; brachial valve interior with low, rounded, median septum and two lateral ridges; pair of elongately-oval muscle scars faintly impressed posterolaterally.



**Figs 57–61** *Karnotreta adnata* gen. et sp. nov. Fig. 57, holotype BB 95414, exterior of pedicle valve,  $\times 9$ ; Fig. 58a, b, paratype BB 95415, exterior of brachial valve: a,  $\times 9$ ; b, enlargement of ornamentation,  $\times 36$ . Fig. 59, paratype BB 95416, interior of incomplete brachial valve,  $\times 9$ ; Fig. 60, paratype BB 95606, interior of brachial valve,  $\times 8$ ; Fig. 61, paratype BB 95417, interior of incomplete brachial valve,  $\times 9$ .

**NAME.** 'Attached'.

**DESCRIPTION.** Small, subcircular, ventribiconvex *Karnotreta*, on average 86% as long as wide, with evenly rounded anterior and lateral margins and truncated, rectimarginate, posterior margin; external surfaces ornamented by fine concentric growth-lines becoming lamellose peripherally and bearing rows of fine, transversely oval to subtriangular, hollow, prone spines with dimensions of up to  $80 \times 35 \mu\text{m}$ ; pedicle valve low, conical in lateral profile, about one-third as high as long, with posteriorly-situated apex; pedicle foramen apical, subcircular, about 80% as wide as long with smoothly rounded anterior and lateral margins tapering slightly posteriorly; ventral beak small, triangular, projecting posteriorly to overhang narrow, broadly triangular, apsacline pseudointerarea divided medially by well-developed, rounded median ridge; propareas narrow, triangular, marked by growth-lines becoming lamellose and spinose dorsally; posterior margin of pedicle foramen with vertical plate projecting dorsally through umbo to form posterior margin of circular pedicle tube on valve interior; posterior margin of pedicle tube adnate medially with inner surface of ventral pseudointerarea, but becoming free posterolaterally; inner surfaces of pedicle tube finely grooved by concentric growth-lines.

Brachial valve gently convex, with faint, triangular, median sulcus, very narrow posteriorly but becoming wider and shallower anteriorly; dorsal umbo small, rounded with triangular beak projecting posteriorly of posterior margin of valve; interior of brachial valve with narrow, thickened, anacline pseudointerarea, strongly grooved by growth-lines, elevated above the valve floor anteriorly and smoothly arched posteromedially to form rounded, convex fold of shell; interior of brachial valve with faint median septum and two lateral ridges; median septum low, rounded, narrow posteriorly but becoming slightly wider anteriorly and running about 50% of valve length; elongately oval muscle scars, 0.9 mm long  $\times$  0.3 mm wide, impressed posterolaterally on valve floor and diverging anteriorly at  $45^\circ$  with median axis of valve.

HOLOTYPE. Pedicle valve, BB 95414: length 3.4 mm, width 4.0 mm. Fig. 57.

	length	width (mm)
PARATYPES. Incomplete pedicle valve; BB 95416	3.3	—
Brachial valve; BB 95415	3.7	3.8
Brachial valve; BB 95606	2.8	2.8
Incomplete brachial valve; BB 95417	—	3.6

TYPE HORIZON AND LOCALITY. Loc. 1.

Genus *MULTISPINULA* Rowell, 1962

*Multispinula attenuata* sp. nov.

Figs 62–65

DIAGNOSIS. Medium-sized, elongately oval *Multispinula*, about three-quarters as wide as long with narrowly rounded posterior margin; ventral pseudointerarea narrow, procline; interior of brachial valve with short median septum.

NAME. 'Thinned, narrowed'.

DESCRIPTION. Elongately oval, dorsibiconvex *Multispinula*, estimated to have attained a maximum length of about 8 mm and a maximum width of 6 mm, anterior margin smoothly rounded, lateral margins rounded, subparallel, tapering slightly posteriorly to narrow, narrowly-rounded, posterior margin; external surfaces marked by concentric growth-lines becoming lamellose peripherally and bearing rows of pustules and hollow, prone spines; pedicle foramen apical, elongately tear-shaped, about 45% as wide as long, and estimated to have been about 40% as long as maximum shell length, with smoothly rounded anterior margin and gently rounded lateral margins tapering posteriorly; posterior margin of pedicle foramen closed by plate which projects obliquely anterodorsally through thickened umbo to form posterior margin of subcircular pedicle tube on inner surface of valve; ventral beak small, triangular, projecting posteriorly to overhang narrowly triangular, procline pseudointerarea divided into narrow triangular propareas by faint median intertrough.

Brachial valve with narrow, thickened pseudointerarea, elevated slightly medially to form low, rounded, convex ridge; floor of brachial valve with low, narrow median septum.

HOLOTYPE. Incomplete pedicle valve, BB 95409. Fig. 62.

PARATYPES. Incomplete pedicle valves, BB 95411, 95605; incomplete brachial valves, BB 95410, 95412.

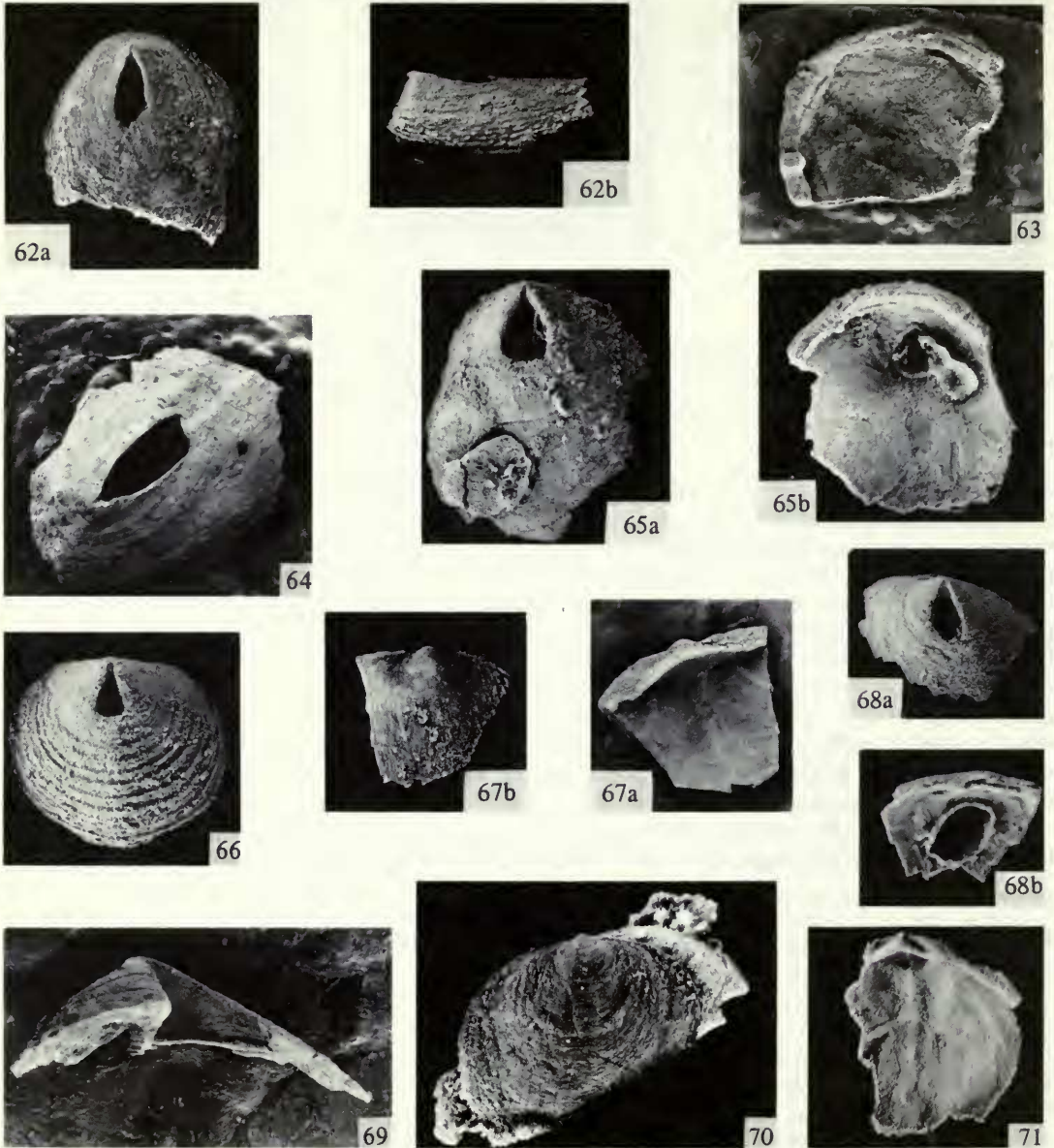
TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. While *M. attenuata* is represented by only a small number of specimens in the Tourmakeady residues, it is sufficiently distinctive to warrant specific identification. *M. attenuata* can readily be distinguished from the other, more common, Tourmakeady species, *M. hibernica*, by its elongate oval shape, proportionately narrower pedicle foramen, and narrower, procline ventral pseudointerarea divided medially by a faint intertrough. Furthermore, there is no sign, in brachial valves of *M. attenuata*, of the pair of lateral ridges which flank the dorsal median septum in *M. hibernica*.

The combination of strongly rounded posterior margin, elongately oval shape, partly closed pedicle foramen, and procline ventral pseudointerarea serves to distinguish *M. attenuata* from previously-described species of *Multispinula*. Thus, *M. subradiata* (Cooper), from the Middle Ordovician Arline formation of Tennessee (Cooper 1956: 269), differs from the new species in having a ventral valve with a strongly acuminate posterior margin and a proportionately longer and narrower pedicle foramen. The brachial valves of the two species are also readily distinguishable, as *M. subradiata* has a strong dorsal sulcation.

*M. cryptotreta* Goryanskii, from the Cambro-Ordovician deposits of the Russian Platform





**Figs 62–65** *Multispinula attenuata* sp. nov. Fig. 62a, b, **holotype** BB 95409, exterior of incomplete pedicle valve: a, ventral view,  $\times 7$ ; b, lateral view  $\times 7$ ; Fig. 63, paratype BB 95410, interior of incomplete brachial valve,  $\times 9$ ; Fig. 64, paratype BB 95411, oblique view of exterior of incomplete pedicle valve,  $\times 9$ ; Fig. 65a, b, paratype BB 95605, exterior and interior of incomplete pedicle valve, both  $\times 6$ .

**Figs 66–71** *Multispinula hibernica* (Reed). Fig. 66, BB 95400, exterior of pedicle valve,  $\times 8$ ; Fig. 67a, b, BB 95401, interior and exterior of incomplete brachial valve: a,  $\times 9$ ; b,  $\times 7$ . Fig. 68a, b, BB 95404, exterior and interior of incomplete pedicle valve, both  $\times 7$ ; Fig. 69, BB 95402, lateral view of incomplete pedicle valve showing pedicle tube,  $\times 19$ ; Fig. 70, BB 95403, exterior of incomplete brachial valve,  $\times 8$ ; Fig. 71, BB 95604, interior of incomplete brachial valve,  $\times 6$ .

(Goryanskii 1969: 96), differs from *M. attenuata* in having a subtriangular brachial valve with a tapering, acuminate, posterior margin. The pedicle valve of *M. cryptotreta* has not been figured, but would, on the evidence of figured brachial valves, certainly differ from that of the Irish species at least in the shape of the posterior margin.

*Multispinula hibernica* (Reed)

Figs 66–71

1909 *Acrotreta ? hibernica* Reed in Gardiner & Reynolds: 150; pl. 6, figs 13a–c.

DIAGNOSIS. Subcircular, ventribiconvex *Multispinula*, with tear-shaped pedicle foramen about one-quarter as long as valve; broadly triangular ventral pseudointerarea divided medially by faint ridge; brachial interior with low, narrow, median septum and two pairs of short, divergent lateral ridges.

DESCRIPTION. Medium-sized, subcircular, ventribiconvex *Multispinula*, about 90% as long as wide, with obtusely rounded posterior margin and smoothly rounded anterior and lateral margins; external surfaces with concentric growth-lines becoming strongly lamellose peripherally and bearing pustules and regular rows of prone, hollow spines up to 35  $\mu$ m in diameter.

Pedicle valve low to moderately conical, about one-third as high as long, with apex situated posteriorly; pedicle foramen apical, tear-shaped, about 60% as wide as long and about 25% as long as valve, smoothly rounded anteriorly and laterally but tapering sharply posteriorly to minute triangular beak; posterior margin of pedicle foramen closed by plate projecting obliquely anterodorsally through thickened ventral umbo to form posterior margin of circular pedicle tube in the valve interior; inner surface of pedicle tube marked by growth-lines; ventral pseudointerarea narrow, broadly triangular, procline to catacline, and divided medially by low ridge becoming fainter dorsally; dorsal margin of pseudointerarea thickened with faint median fold.

Interior of pedicle valve with pair of circular muscle scars, 0.9 mm in diameter, impressed posterolaterally on either side of pedicle tube; pair of oval cardinal muscle scars, 1 mm long  $\times$  0.3 mm wide, impressed anterolaterally of circular muscle scars, and diverging anteriorly at 45° from median axis of valve; anteromedian wall of cardinal muscle scars thickened, occasionally elevated to form convex boss of shell on valve floor.

Brachial valve gently convex, with swollen, rounded umbo projecting posteriorly of posterior margin of valve; dorsal pseudointerarea narrow, adnate, anacline, marked by concentric growth-lines and becoming pustulose and spinose posterolaterally; pseudointerarea smoothly elevated medially, with rounded anterior margin overhanging valve floor; floor of valve with short, low, median septum extending 3 mm anteriorly from beneath pseudointerarea, with a pair of low ridges branching off at about two-thirds of its length and diverging anteriorly at 60° from median axis of valve; two short, narrow, lateral ridges additionally impressed posterolaterally on floor of valve and diverge anteriorly at 30° from median axis of valve; pair of faint, elongately oval, muscle scars, 1.2 mm long  $\times$  0.6 mm wide, impressed symmetrically within the angles subtended by the posterior pair of lateral ridges and the median septum, and diverging anteriorly at 30° from median axis of valve; two pairs of faint, oval, muscle scars, corresponding to transmedian (?) and central (?) muscles, impressed symmetrically immediately lateral of branching ridges.

FIGURED MATERIAL. Pedicle valve: BB 95400 (length 3.3 mm, width 3.7 mm); incomplete pedicle valves: BB 95402, 95404; incomplete brachial valves: BB 95401, 95403, 95604. Loc 1.

DISCUSSION. The genus *Multispinula* was erected to incorporate species previously assigned to *Schizambon*, but distinguished from that genus by having peripheral spines arranged regularly along the anterior margin of concentric lamellar growth-lines, a narrow ventral pseudointerarea, and an internal pedicle tube (Rowell 1962: 148). In addition, species of



*Multispinula* are generally about two or three times larger than most *Schizambon*. On the basis of these criteria the Tourmakeady material clearly belongs to *Multispinula*.

*M. hibernica* was first described, as *Acrotreta* (?) *hibernica*, by Reed (1909), who recovered a single pedicle valve and its external mould from the Tourmakeady Limestone exposed in the 'upper part of Stream F' (Reed in Gardiner & Reynolds 1909: 150). During the course of the present study a much larger sample was recovered from this same locality, including previously undescribed brachial valves, and an extensive revision of Reed's original description became necessary. In particular it is now clear, from an examination of his specimen (SM A10372a, b), that Reed was in error when he stated 'the apex of the valve being broken off, it is uncertain whether a foramen was present'. In fact the valve is complete, with the large apical foramen characteristic of *Multispinula*. In addition, a close examination of the ventral pseudointerarea of Reed's specimen reveals that it is divided medially by a distinct ridge rather than a 'broad median shallow groove'.

When compared with the type species of *Multispinula*, *M. macrothyris* (Cooper) from the Middle Ordovician Benbolt formation of Virginia (Cooper 1956: 267), *M. hibernica* differs in shape, being rounded rather than elongately oval, and has a proportionately smaller pedicle foramen and a much more conical pedicle valve. *M. hibernica* also differs in lacking a dorsal sulcus and radial ornamentation.

The posterior margin of a pedicle valve fragment of *Multispinula* sp. from the L. Ordovician Antelope Valley Limestone of southern Nevada (Krause & Rowell 1975: 68) is similar to that of *M. hibernica*, but differs in having an apsacline ventral pseudointerarea and a proportionately wider pedicle foramen.

*Multispinula* is also known from the Ordovician of Kazakhstan, but *M. parvula* Popov (1980: 117) is readily distinguishable from *M. hibernica*, as the former has a strong sulcation in the brachial valve and radial ornamentation.

### Superfamily indet.

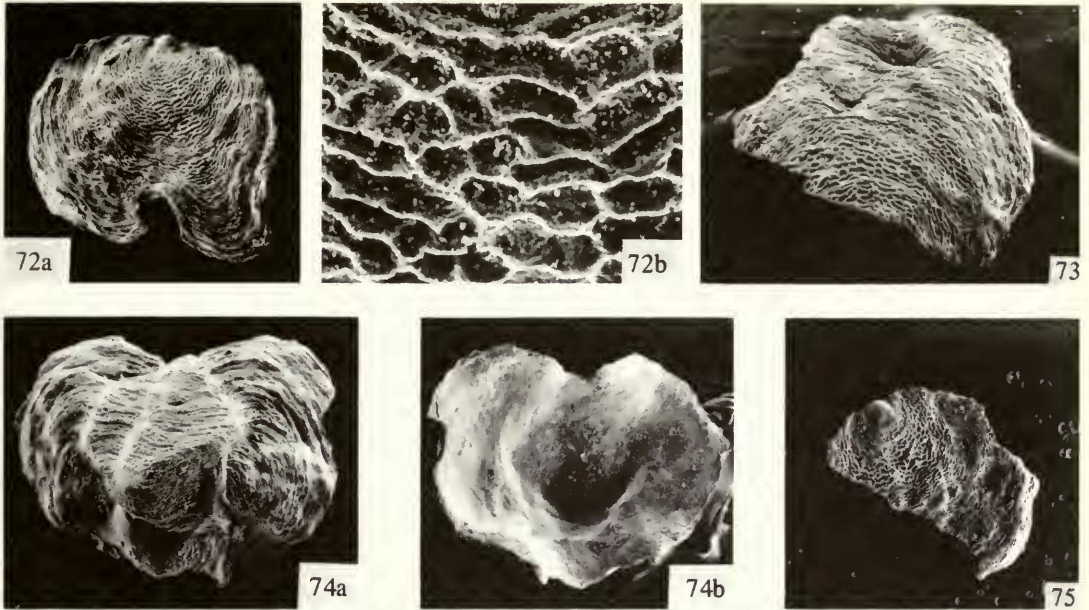
#### Inarticulata, gen. et sp. indet.

##### Figs 72–75

The Tourmakeady Limestone exposed at Loc. 1 contained a small sample of a distinctively ornamented inarticulate species. The specimens (BB 95441–95444) are mostly incomplete, but reconstructions indicate that complete valves were very variable in shape, with a maximum dimension of about 3.5 mm. The least distorted specimen (BB 95441), which is complete and measures 1.8 mm in length  $\times$  2.2 mm in width, has an almost straight posterior margin and subparallel, irregular lateral margins. The anterior margin of this specimen is strongly bilobed, with a narrow, posteriorly rounded, anteromedian notch separating rounded, asymmetrical, anterolateral lobes. Other fragments also show evidence of an anteromedian notch. The lateral profile of these specimens is also very variable, ranging from almost flat to moderately conical. Maximum convexity is usually developed anteriorly, while the posterior and posterolateral regions of the valve are often flattened. The external surfaces are very irregular, and ornamented by fine, elevated, discontinuous, concentric fila, numbering about 40 per mm medially. The concentric fila are crossed by short, impersistent radial fila which give rise to an irregular reticulate pattern. Internally the valves are featureless, save for the hollows and ridges corresponding to the external surface irregularities.

The taxonomic affinities of these specimens are problematical. None shows evidence of attachment scars, although their distorted morphology strongly suggests a cemented mode of life. Presumably, therefore, the sample consists of the brachial valves of a genus which was cemented by a pedicle valve which has not been recovered. Cementation is common amongst the Craniacea, but all genera assigned to that superfamily are characterized by holoperipheral, or more rarely mixoperipheral, growth, while the Tourmakeady specimens clearly grew by hemiperipheral accretion. In addition, now that the Eoconulidae have been removed





**Figs 72–75** *Inarticulata*, gen. et sp. indet. Fig. 72a, b, BB 95441, brachial(?) valve exterior: a,  $\times 15$ ; b, ornamentation,  $\times 110$ ; Fig. 73, BB 95444, brachial(?) valve fragment,  $\times 19$ ; Fig. 74a, b, BB 95442, exterior and interior of brachial(?) valve, both  $\times 17$ ; Fig. 75, BB 95443, exterior of incomplete brachial(?) valve,  $\times 19$ .

from the superfamily (Krause & Rowell 1975: 798), all craniaceans are calcareous-shelled, in contrast to the chitinophosphatic shell substance of the Tourmakeady valves.

The external ornamentation of the Tourmakeady specimens is similar to that of some species of the paterinacean genus *Micromitra*. However, the brachial valve of genera assigned to the Paterinacea has a well-developed homochilidium, a feature which is not evident in the Tourmakeady specimens, effectively precluding them from that superfamily. Indeed, because of the paucity of the sample, and the absence of information on the morphology of the pedicle valve, it is impossible to assign these specimens to any established inarticulate superfamily.

Class **ARTICULATA** Huxley, 1869

Order **ORTHIDA** Schuchert & Cooper, 1932

Suborder **ORTHIDINA** Schuchert & Cooper, 1932

Superfamily **ORTHACEA** Woodward, 1852

Family **EOORTHIDAE** Walcott, 1908

Genus **APHEOORTHIS** Ulrich & Cooper, 1936

*Apheoorthis* sp.

Figs 76–79

**DIAGNOSIS.** Large, semicircular to subquadrate *Apheoorthis*, about nine-tenths as long as wide, external surfaces multicostellate with 5 ribs per mm at 5 mm anteromedially of dorsal umbo.

DESCRIPTION. Large, semicircular to subquadrate *Apheoorthis*, estimated to have attained a maximum length of about 10 mm and to be about 90% as long as wide; external ornamentation multicostellate with 5 rounded ribs per mm at 5 mm anteromedially of dorsal umbo; ventral interarea very narrow, apsacline, with open delthyrium; dorsal interarea very narrow, anacline.

Ventral interior with well-defined converging dental plates sloping down to valve floor to define narrow, posteriorly-tapering, elongately subtriangular, tripartite pseudospondylium with narrow, tongue-shaped, median adductor scar and measuring 2.2 mm × 1.6 mm in one specimen.

FIGURED MATERIAL. Incomplete conjoined valves, BB 95586; incomplete pedicle valves, BB 95583-5. Loc. 1.

DISCUSSION. *Apheoorthis* is sparsely represented in the Tourmakeady residues, and not much reliable information can be ascertained about the dorsal interior. However, the presence of a well-defined, tripartite pseudospondylium in the pedicle valve, combined with characteristic shell outline and profile, suggests that these specimens can be assigned to *Apheoorthis*. A comparison with previously-described species of *Apheoorthis* from North America, such as *A. ornata* Ulrich & Cooper (1938: 86) from the Lower Ordovician of Oklahoma, confirms the similarity in the internal morphology of the pedicle valve. The Irish specimens appear to be much more finely multicostellate than those from North American successions, many of which are also fascicostellate. Specific recognition of the Tourmakeady specimens, however, has been withheld until the internal morphology of the brachial valve is known.

#### Family HESPERONOMIIDAE Ulrich & Cooper, 1936

##### Genus *PROTOHESPERONOMIA* nov.

DIAGNOSIS. Small, transversely subquadrate to semicircular hesperonomiid, pedicle valve gently convex becoming geniculate when adult; brachial valve gently concave to planar when juvenile, becoming gently to moderately convex in later growth stages; external ornamentation unequally parvicostellate composed of fine, rounded, ribs divided into narrowly triangular sectors by a thickening of regularly-spaced primary ribs.

Ventral interior with small triangular teeth supported by curved dental plates, widely divergent dorsally but becoming subparallel ventrally and forming posterolateral margins of strongly bilobed ventral muscle platform; ventral mantle canal system unknown.

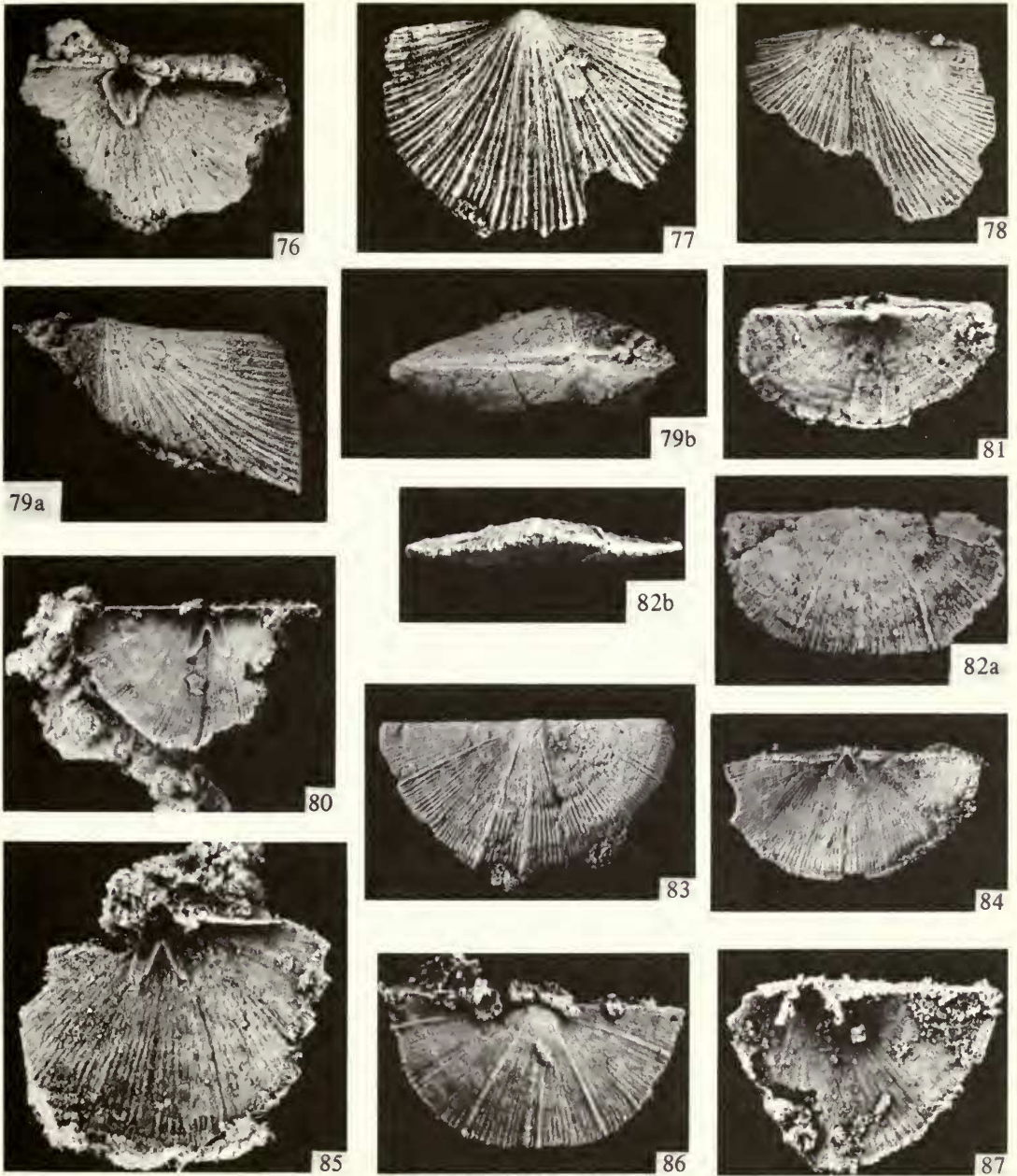
Dorsal interior with long, thin, flat-lying brachiophores, diverging anteriorly and flanked laterally by shallow, narrowly-triangular sockets; brachiophores supported by weak, convergent brachiophore bases united with floor of valve to form poorly-defined, flat-lying, narrowly triangular notothyrial platform; dorsal mantle canal system unknown.

NAME. An early relative of *Hesperonomia*.

TYPE SPECIES. *Protohesperonomia resupinata* sp. nov. from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The Tourmakeady residues yielded a number of shells with a well-defined unequally parvicostellate ornamentation, characterized internally by simple brachiophores and strongly bilobed ventral muscle scars. These features, along with the narrow profile of the shells, indicate that the affinities of these specimens lie with the Hesperonomiidae. Within this small family, the new Irish genus is most similar to *Hesperonomia* Ulrich & Cooper in the form of the dorsal cardinalia. However, *Hesperonomia* is readily distinguished from *Protohesperonomia* by the presence of a prominent cardinal process which is not seen in any of the Irish specimens. Furthermore, the lateral muscle scars in the ventral valve of *Hesperonomia* are not so well developed, and the ventral muscle field in this genus has a subquadrate outline rather than the 'tuning-fork' shape of *Protohesperonomia*. Externally the new genus is also readily distinguishable, as a well-defined, unequally parvicostellate





**Figs 76–79** *Apheoorthis* sp. Fig. 76, BB95585, interior of incomplete pedicle valve,  $\times 4$ ; Fig. 77, BB95583, exterior of incomplete pedicle valve,  $\times 8$ ; Fig. 78, BB95584, exterior of incomplete pedicle valve,  $\times 3$ ; Fig. 79a, b, BB95586, ventral and posterior views of incomplete conjoined valves, both  $\times 4$ .

**Figs 80–87** *Protohesperonomia resupinata* gen. et sp. nov. Fig. 80, holotype BB95502, interior of incomplete pedicle valve,  $\times 6$ ; Fig. 81, paratype BB95504, dorsal view of juvenile conjoined valves,  $\times 7$ ; Fig. 82a, b, paratype BB95507, ventral and anterior views of juvenile conjoined valves, both  $\times 8$ ; Fig. 83, paratype BB95505, exterior of resupinate pedicle valve,  $\times 5$ ; Fig. 84, paratype BB95503, interior of brachial valve,  $\times 5$ ; Fig. 85, paratype BB95508, interior of incomplete pedicle valve,  $\times 6$ ; Fig. 86, paratype BB95509, ventral view of conjoined valves,  $\times 6$ ; Fig. 87, paratype BB95506, interior of incomplete brachial valve,  $\times 6$ .



ornamentation and peripheral geniculation are features not seen in other hesperonomiid genera.

*Protohesperonomia* is at present monospecific, and known only from the Tourmakeady Limestone.

*Protohesperonomia resupinata* sp. nov.

Figs 80–87

**DIAGNOSIS.** Small, transversely subquadrate to semicircular *Protohesperonomia* averaging 50% as long as wide, gently convex pedicle valve becoming geniculate when adult and with a maximum thickness averaging 38% of valve length, brachial valve gently concave to planar when juvenile, becoming gently to moderately convex when adult, averaging 25% as deep as long; external ornamentation unequally parvicostellate with 8–9 rounded ribs per mm at 2 mm anteromedially of dorsal umbo and divided into narrowly triangular sectors by a thickening of every seventh to tenth rib.

**NAME.** 'Lying on its back'.

**DESCRIPTION.** Small, transversely subquadrate to semicircular *Protohesperonomia* averaging 50% as long as wide (l mm (var l) 3.53 (0.71),  $\bar{w}$  mm (var w) 7.03 (3.51),  $r = 0.992$ ;  $n = 11$ ), pedicle valve gently convex averaging in 2 valves 20% as deep as long when juvenile but becoming geniculate when adult and averaging 38% as deep as long (range 36–41%;  $n = 3$ ); brachial valve gently concave to planar when juvenile becoming gently to moderately convex when adult, attaining a maximum thickness averaging 25% of valve length (range 24–26%;  $n = 3$ ); cardinal extremities acutely rounded, lateral and anterior margins smoothly rounded, brachial valve with broad, gently rounded, median sulcus corresponding to subdued median carina on pedicle valve and bearing one or two swollen ribs medially; external ornamentation unequally parvicostellate with 8 and 9 rounded ribs per mm at 2 mm anteromedially of umbones of 1 and 2 brachial valves respectively, and divided into narrowly triangular sectors by a thickening of every seventh to tenth rib; ventral interarea narrow, planar, catacline, with open delthyrium, dorsal interarea narrow, planar, anacline, notothyrium open.

Ventral interior with small triangular teeth supported by curved dental plates widely divergent dorsally but becoming subparallel ventrally and forming posterolateral margins of strongly bilobed ventral muscle field extending anteriorly for an average of 29% (range 28–31%;  $n = 4$ ) of valve length, defined by elevated rims of shell and composed of two anteriorly rounded lobes diverging anteriorly at 30° with median axis of valve and each averaging 27% as long as wide; lobes of ventral muscle field uniting posteromedially on either side of small, elevated, rounded, posteriorly tapering boss of shell.

Dorsal interior with thin, flat-lying brachiophores diverging anteriorly at angle of 60°, extending anteriorly for an average of 25% of valve length in 2 valves and flanked laterally by shallow, narrowly triangular sockets, brachiophores supported by weak, convergent brachiophore bases united with floor of valve to form poorly-defined, flat-lying, narrowly triangular notothyrial platform, rounded anteriorly and with dimensions of 0.7 × 0.6 mm and 0.7 × 0.7 mm in 2 specimens.

**HOLOTYPE.** Incomplete pedicle valve; BB 95502. Fig. 80.

PARATYPES.		length	width (mm)
Conjoined valves; BB 95504a, b		3.0	5.3
Conjoined valves; BB 95507a, b		2.7	6.1
Conjoined valves; BB 95509a, b		3.6	6.7
Pedicle valve; BB 95505		4.8	9.1
Incomplete pedicle valve; BB 95508		5.8	—
Brachial valve; BB 95503		4.1	—
Incomplete brachial valve; BB 95506		4.5	—

**TYPE HORIZON AND LOCALITY.** Loc. 1.

Family **ORTHIDIELLIDAE** Ulrich & Cooper, 1936Genus **ORTHIDIUM** Hall & Clarke, 1892*Orthidium* cf. *gemmiculum* (Billings)

Figs 88–90

cf. 1865 *Orthis gemmicula* Billings: 75cf. 1892 *Orthidium gemmicula* (Billings) Hall & Clarke: 217cf. 1938 *Orthidium gemmiculum* (Billings); Ulrich & Cooper: 112

DIAGNOSIS. Small, subcircular to transversely oval *Orthidium*, with a moderately to strongly convex pedicle valve averaging 90% as long as wide and 34% as deep as long, and a smoothly convex brachial valve averaging 77% as long as wide and 47% as deep as long; ornamented by 8–9 rounded ribs per mm at 2 mm anteromedially of dorsal umbo, and regularly-spaced concentric lamellae extended peripherally as frills.

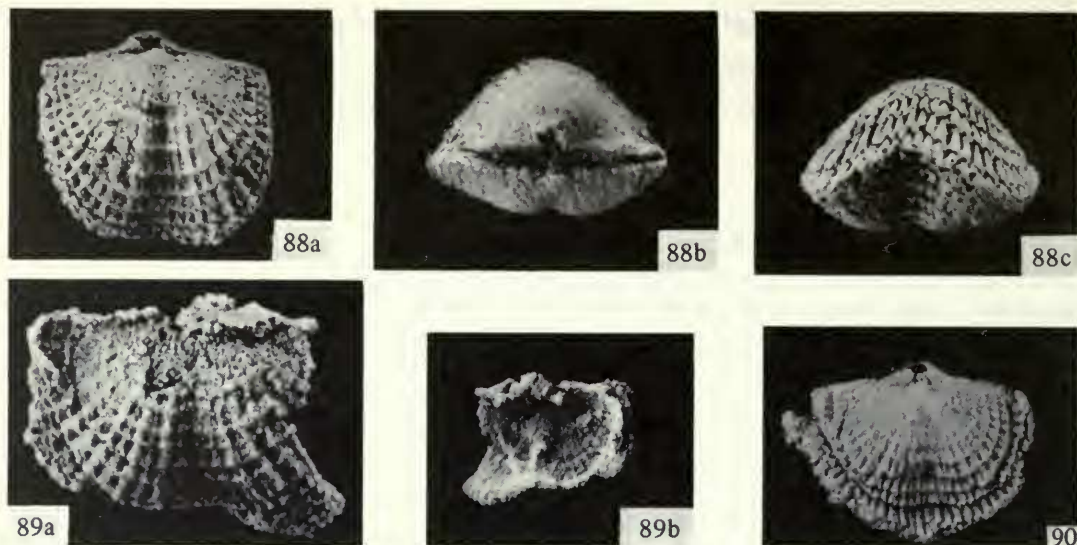
DESCRIPTION. Small subcircular to transversely oval *Orthidium*; pedicle valve moderately to strongly convex, averaging 90% as long as wide (range 86–95%;  $n = 4$ ) and 34% as deep as long (range 31–36%;  $n = 4$ ); brachial valve smoothly convex, averaging 77% as long as wide (range 75–82%;  $n = 4$ ) and with a maximum depth averaging 47% of valve length (range 42–53%;  $n = 4$ ) developed at strongly sulcate anteromedian margin; lateral margins of both valves smoothly rounded, anterior margins bilobed by sulcation; external ornamentation costellate with 8 and 9 rounded ribs per mm at 2 mm anteromedially of umbones of 2 and 4 brachial valves respectively, costellae crossed by regularly-spaced concentric lamellae with an average separation of 0.3 mm (range 0.3–0.4 mm) and 0.26 mm (range 0.2–0.3 mm) along the median axis of two adult brachial valves, concentric lamellae strongly developed in later growth stages and extending peripherally up to one mm as thin, flat-lying, concentric frills; brachial valve with well-developed rounded sulcus with an average maximum width of 1.1 mm in 4 adult brachial valves (range 0.9–1.2 mm); ventral interarea triangular, curved, apsacline with open delthyrium, dorsal interarea very narrow, anacline.

Ventral interior with large, thickened, triangular teeth flanked by well-developed crural fossettes and supported by erect dental plates obscured by callus deposits.

Dorsal interior with massive, tongue-shaped, cardinal process with dimensions of 0.6 × 0.7 mm and 0.7 × 0.8 mm in two specimens and recurved posteriorly to occupy delthyrium of pedicle valve in conjoined valves; brachiophores narrowly triangular, thickened, erect, extending ventrally 0.6 mm above valve floor in one specimen, and united laterally with cardinal process by callus deposits to form massive unified cardinalia flanked by broadly triangular sockets; floor of valve with low rounded ridge extending anteriorly for 1.5 mm and 1.9 mm in two adult valves; two pairs of adductor scars impressed on floor of valve extending forwards for about 48% of the length of the valve and symmetrically disposed on either side of median ridge and defined laterally by low elevated ridges, posterior pair tear-shaped, and with median axis inclined at 45° to median axis of valve, anterior pair elongately oval and subparallel with median axis of valve.

FIGURED MATERIAL. Conjoined valves, BB 95466a, b (length 2.6 mm, width 2.9 mm), BB 95468 (length 3.1 mm, width 3.6 mm); brachial valve BB 95467. Loc. 1.

DISCUSSION. Although sparsely represented in the Tourmakeady residues, the diagnostic features of *Orthidium* are so striking that its recognition is unequivocal. In particular the massive cardinalia and distinctive concentric lamellose ornamentation are diagnostic of this relatively rare genus. *Orthidium* is known primarily from North America, having been recorded from low–middle Ordovician successions in Quebec, Newfoundland, and Nevada. Previously-described species display many morphological similarities, but there are details of shell proportion and ornamentation which distinguish them and which confirm the close affinity between the Irish specimens and *O. gemmiculum* from the Lower Ordovician Levis Shales of Quebec (Ulrich & Cooper 1938: 112). Thus the length/width ratios for the pedicle



**Figs 88–90** *Orthidium* cf. *gemmiculum* (Billings). Fig. 88a, b, c, BB 95466, dorsal, posterior and anterior views of conjoined valves, all  $\times 11$ ; Fig. 89a, b, BB 95467, exterior and anterior views of incomplete brachial valve; a,  $\times 16$ ; b,  $\times 10$ . Fig. 90, BB 95468, dorsal view of conjoined valves,  $\times 8$ .

and brachial valve of the Canadian species are 86% and 75% respectively, as compared with 90% and 77% respectively for the Irish specimens. Canadian *O. gemmiculum* is slightly more finely costellate than the present Irish representatives but, in the absence of other distinguishing features, this difference is not considered sufficient to form the basis of a new taxon. The other described species are considerably more coarsely costellate than the Quebec and Irish specimens.

Family **ORTHIDAE** Woodward, 1852

Subfamily **ORTHINAE** Woodward, 1852

Genus **ARCHAEORTHIS** Schuchert & Cooper, 1931

*Archaeorthis globosa* sp. nov.

Figs 91–94

**DIAGNOSIS.** Small, transversely oval to subquadrate *Archaeorthis* with slight inward geniculation in adult shells, pedicle valve moderately to strongly convex averaging 59% as long as wide and 39% as deep as long, brachial valve strongly convex posteromedially, becoming gently convex peripherally, and averaging 56% as long as wide and 37% as deep as long; external ornamentation fascicostellate with 5–7 ribs per mm at 2 mm anteromedially of dorsal umbo.

**NAME.** 'Rounded'.

**DESCRIPTION.** Small, transversely oval to subquadrate, ventribiconvex *Archaeorthis*; pedicle valve moderately to strongly convex averaging 59% as long as wide and 39% as deep as long ( $\bar{l}$  mm (var l) 2.35 (0.833),  $\bar{w}$  mm (var w) 3.91 (1.77),  $r = 0.965$ ;  $n = 77$ .  $\bar{l}$  mm (var l) 3.32 (0.199),  $\bar{th}$  mm (var th) 1.28 (0.043),  $r = 0.860$ ;  $n = 16$ ); brachial valve strongly convex posteromedially becoming gently convex peripherally and averaging 56% as long as wide and



with a maximum thickness developed at sulcate anterior margin averaging 37% of valve length ( $\bar{l}$  mm (var l) 2.17 (0.961),  $\bar{w}$  mm (var w) 3.98 (1.828),  $r = 0.937$ ;  $n = 68$ .  $\bar{l}$  mm (var l) 3.01 (0.890),  $\bar{t}$  mm (var th) 1.12 (0.472),  $r = 0.847$ ;  $n = 12$ ); peripheral margins of adult valves smoothly rounded with slight inward geniculation; external ornamentation fascicostellate with 5, 6 and 7 ribs per mm at 2 mm anteromedially of umbones 14, 15 and 9 brachial valves, respectively; brachial valve with narrow angular sulcus very faint posteriorly but becoming broader anteriorly to average 1.1 mm in width (range 0.9–1.2 mm;  $n = 18$ ) at 2 mm anteromedially of dorsal umbo, and corresponding to moderately or strongly defined carina on pedicle valve; ventral interarea triangular, gently curved, apsacline to catacline, with open delthyrium; dorsal interarea narrow, anacline.

Ventral interior with short triangular teeth extending dorsally for an average of 18% (range 15–20%;  $n = 5$ ) of the length of the ventral interarea and supported by short, strongly receding, subparallel dental plates; ventral muscle field equidimensional to transversely oval, averaging 92% as long as wide (range 78–100%;  $n = 5$ ) and defined anteriorly by elevated, anteriorly convex, rim buttressed by prominent, elongate, anteriorly sloping, posteriorly tapering, callus averaging 62% as wide as long ( $\bar{l}$  mm (var l) 1.44 (0.049),  $\bar{w}$  mm (var w) 0.90 (0.047),  $r = 0.887$ ;  $n = 13$ ); up to 3 narrow branches, 0.1–0.2 mm in diameter, of digitate mantle canal system impressed posterolaterally of median callus.

Dorsal interior with flattened, blade-like, blunt, divergent brachiophores extending for 53% and 29% of valve length in two specimens, flanked by narrow, triangular sockets; notothyrial platform triangular, equidimensional to transversely elongate, on average 90% as long as wide ( $\bar{l}$  mm (var l) 0.607 (0.005),  $\bar{w}$  mm (var w) 0.68 (0.006),  $r = 0.685$ ;  $n = 14$ ) buttressed by low, rounded, median ridge extending anteriorly on average for 65% of valve length (range 56–74%;  $n = 5$ ); floor of valve with two pairs of adductor scars impressed symmetrically on either side of median ridge; anterior pair elongately oval with long axis aligned parallel with median ridge and averaging 55% as wide as long (range 50–58%;  $n = 4$ ); posterior pair of adductor scars tear-shaped, tapering posteriorly, on average 65% as wide as long (range 62–67%;  $n = 3$ ) with longitudinal axes diverging anteriorly at angle of 50° from median axis of valve.

HOLOTYPE. Pedicle valve, BB 95461: length 2.9 mm, width 5.0 mm. Fig. 91.

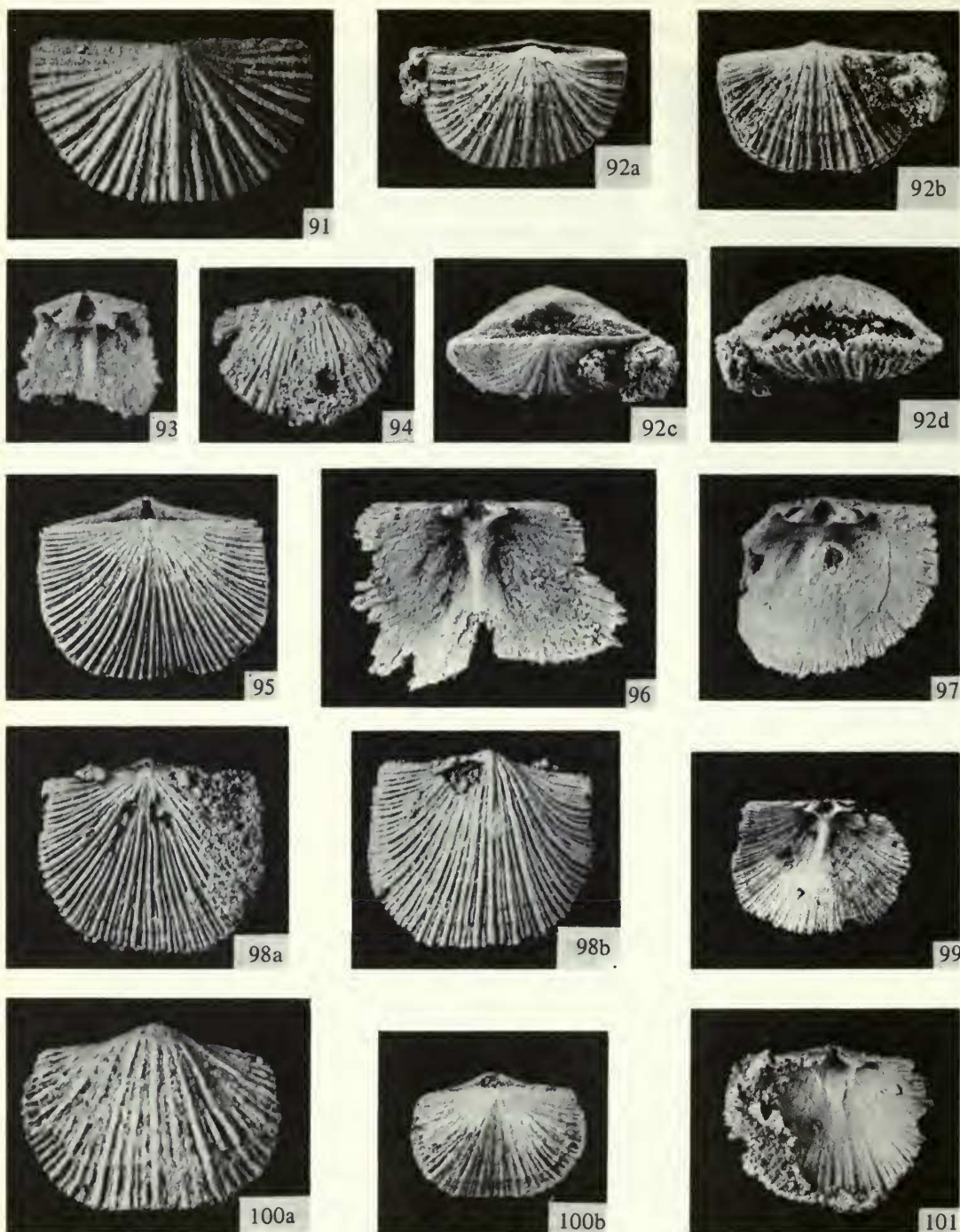
	length	width (mm)
PARATYPES. Conjoined valves; BB 95463a, b	3.6	5.4
Pedicle valve; BB 95464	3.4	5.0
Brachial valve; BB 95462	2.8	4.0
Incomplete brachial valve; BB 95465	–	–

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. It is noteworthy that the sample of *Archaeorthis* recovered from the Tourmakeady Limestone includes a preponderance of complete conjoined valves, which have afforded an unusually comprehensive understanding of the morphology of the species.

*Archaeorthis* is known mainly from the older Ordovician successions in North America, but the Irish specimens can confidently be assigned to this genus by virtue of the diagnostic association of premuscular callosity in the pedicle valve and orthid cardinalia. The peripheral geniculation, along with details of ornamentation and shell shape, immediately distinguishes *A. globosa* from previously-described species of the genus. Apart from lacking geniculation, North American species generally have a costellate ornamentation and a prominent ventral umbo. In addition the strongly transversely oval outline of *A. globosa* differs markedly from the elongately oval or slightly transversely oval shape of North American stocks.

*A. subcarinata* (Laurie 1980: 16), from the Lower Ordovician of Australia, is readily distinguished by its subcircular outline, absence of geniculation, and much finer ribbing. *A. pribyli* (Havlíček 1949), from the late Arenig of Bohemia, is also distinguished from *A. globosa* by its subcircular outline and lack of peripheral geniculation.



**Figs 91–94** *Archaeorthis globosa* sp. nov. Fig. 91, holotype BB 95461, exterior of pedicle valve,  $\times 8$ ; Fig. 92a, b, c, d, paratype BB 95463, ventral, dorsal, oblique posterior and anterior views of conjoined valves, all  $\times 6$ ; Fig. 93, paratype BB 95565, interior of incomplete brachial valve,  $\times 7$ ; Fig. 94, paratype BB 95462, exterior of incomplete brachial valve,  $\times 7$ .

**Figs 95–101** *Nothorthis pennsylvanica* Ulrich & Cooper. Fig. 95, BB 95593, dorsal view of conjoined valves,  $\times 5$ ; Fig. 96, BB 95599, interior of incomplete brachial valve,  $\times 7$ ; Fig. 97, BB 95595, interior of incomplete brachial valve,  $\times 4$ ; Fig. 98a, b, BB 95598, dorsal and ventral views of conjoined valves,  $\times 6$ ; Fig. 99, BB 95596, interior of incomplete brachial valve,  $\times 4$ ; Fig. 100a, b, BB 95597, ventral and dorsal views of conjoined valves: a,  $\times 8$ ; b,  $\times 5$ ; Fig. 101, BB 95594, interior of pedicle valve,  $\times 4$ .



Genus *NOTHORTHIS* Ulrich & Cooper, 1938*Nothorthis pennsylvanica* Ulrich & Cooper

Figs 95–101

1938 *Nothorthis pennsylvanica* Ulrich & Cooper: 107

DIAGNOSIS. Medium-sized, transversely oval or semicircular to subquadrate *Nothorthis*, pedicle valve moderately to strongly convex, averaging 73% as long as wide and 41% as deep as long; brachial valve gently convex, averaging 69% as long as wide and 25% as deep as long; external ornamentation multicostellate, with 5 to 8 ribs per mm at 5 mm anteromedially of dorsal umbo.

DESCRIPTION. Medium-sized, transversely oval or semicircular to subquadrate ventribiconvex *Nothorthis*; pedicle valve moderately to strongly convex, averaging 73% as long as wide and 41% as deep as long ( $\bar{l}$  mm (var l) 3.81 (0.715),  $\bar{w}$  mm (var w) 5.20 (0.818),  $r = 0.863$ ;  $n = 70$ ).  $\bar{l}$  mm (var l) 5.25 (0.529),  $\bar{th}$  mm (var th) 2.17 (0.111),  $r = 0.767$ ;  $n = 21$ ); brachial valve gently convex to almost plane, averaging 69% as long as wide and 25% as deep as long ( $\bar{l}$  mm (var l) 3.92 (0.520),  $\bar{w}$  mm (var w) 5.67 (0.682),  $r = 0.809$ ;  $n = 50$ ).  $\bar{l}$  mm (var l) 4.84 (0.543),  $\bar{th}$  mm (var th) 1.30 (0.178),  $r = 0.715$ ;  $n = 10$ ); lateral margins of both valves strongly and evenly rounded, anterior margins smoothly and gently rounded; external ornamentation multicostellate, with ribs branching predominantly internally (e.g. 1 $\bar{a}$  $\bar{l}$ , 1 $\bar{a}$ , 1 $\bar{b}$ , 1, 2 $\bar{a}$  $\bar{l}$ , 2 $\bar{a}$ , 2 $\bar{b}$ , 2, 3 $\bar{a}$  $\bar{l}$ , 3 $\bar{a}$ , 3 $\bar{b}$ , 3), only rarely branching externally (e.g. 3 $\bar{a}$  first external in 5 out of 12 brachial valves), ribs numbering 5–8 per mm at 5 mm anteromedially of umbo of 5, 8, 3 and 1 brachial valves respectively; brachial valve with shallow, smoothly rounded sulcus, narrow posteriorly but becoming broader anteriorly; ventral interarea narrow, curved, apsacline, with open delthyrium, dorsal interarea narrow, anacline.

Ventral interior with thickened triangular teeth extending anteriorly on average for 19% of valve length ( $\bar{l}$  mm (var l) 5.28 (0.551),  $\bar{l}_{te}$  mm (var  $l_{te}$ ) 0.97 (0.030),  $r = 0.542$ ;  $n = 16$ ) supported by short, curved, receding, divergent dental plates; floor of valve with undifferentiated, slightly elevated, muscle attachment platform, tongue-shaped to elongately oval in outline, with moderately thickened anterior and anterolateral margins, on average 81% as wide as long ( $\bar{l}$  mm (var l) 1.16 (0.067),  $\bar{w}$  mm (var w) 0.94 (0.054),  $r = 0.902$ ;  $n = 22$ ).

Dorsal interior with blunt, thickened brachiophores, triangular in cross section, flanked by deep, oblique triangular sockets defined anterolaterally by slightly elevated anterior margin of triangular, concave, fulcral plates; brachiophore bases extending on average for 12% of valve length ( $\bar{l}$  mm (var l) 4.77 (0.609),  $\bar{l}_b$  mm (var  $l_b$ ) 0.62 (0.022),  $r = 0.855$ ;  $n = 10$ ) and 34% of lateral extension of sockets ( $\bar{l}_b$  mm (var  $l_b$ ) 0.62 (0.016),  $\bar{w}_{so}$  mm (var  $w_{so}$ ) 1.83 (0.164),  $r = 0.777$ ;  $n = 13$ ); notothyrial platform well-defined, thickened, transversely oval to semicircular, on average 81% as long as wide ( $\bar{l}_n$  mm (var  $l_n$ ) 0.59 (0.020),  $\bar{w}_n$  mm (var  $w_n$ ) 0.73 (0.015),  $r = 0.630$ ;  $n = 18$ ); floor of valve with short, low, median ridge extending on average for 39% of valve length ( $\bar{l}$  mm (var l) 4.49 (0.739),  $\bar{l}_s$  mm (var  $l_s$ ) 1.76 (0.204),  $r = 0.841$ ;  $n = 14$ ); dorsal muscle scars poorly defined, consisting of two pairs of elongately oval scars measuring 0.6 × 0.3 mm in two valves, situated posterolaterally on valve floor and flanking median ridge.

		length	width (mm)
FIGURED MATERIAL.	Conjoined valves; BB 95593a, b	5.0	5.9
	Conjoined valves; BB 95597a, b	3.6	5.3
	Conjoined valves; BB 95598a, b	5.0	5.6
	Pedicle valve; BB 95594	4.9	6.4
	Brachial valve; BB 95595	6.2	—
	Brachial valve; BB 95596	4.6	—
	Incomplete brachial valve; BB 95599	—	—

All Loc. 1.



DISCUSSION. *Nothorthis* is a rare genus, although it is one of the most abundant constituents of the Tourmakeady fauna. Previously described species display a high degree of morphological similarity, so that distinction between different stocks is likely to depend on quantitatively defined characteristics. So far such data exist only for the Tourmakeady specimens which do, however, compare very closely with *N. pennsylvanica* Ulrich & Cooper, from the Lower Ordovician Beekmantown Formation of south-eastern Pennsylvania, in the nature of the cardinalia and in the shell proportions of the figured specimens of the American stock. Ulrich & Cooper (1938: 107) considered the slightly elevated ventral muscle platform of *N. pennsylvanica* to be diagnostic of the species and, in this feature, the Irish and American valves are indistinguishable.

A feature of the statistical data derived for the Tourmakeady *Nothorthis* is the high degree of variability in shape parameters, as reflected in the relatively low values for the coefficient of correlation ( $r$ ). This variability is discernible both in the shape of the shell and in internal structures. The variability is partly an expression of the relatively narrow size range of the stock; but there is also an inherently greater morphological variability than usual in most features. However, attempts to isolate separate sub-groups within the Tourmakeady sample on the basis of shell proportions failed, in the face of demonstrable gradations from, for example, strongly transversely oval shells to semicircular or occasionally elongately oval ones.

#### Genus *ORTHAMBONITES* Pander, 1830

##### *Orthambonites* cf. *panderiana* (Hall & Clarke)

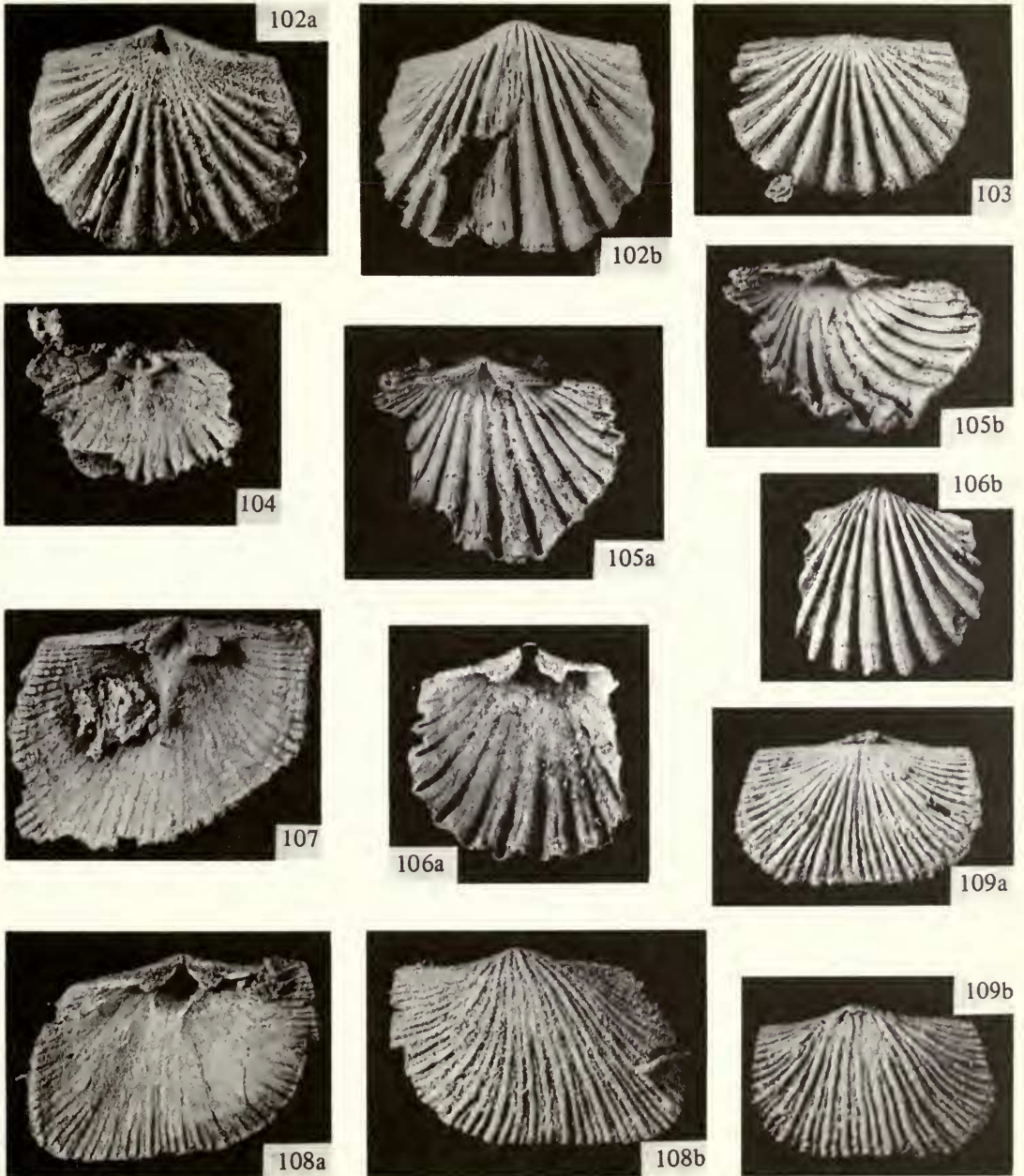
Figs 102–106

- cf. 1865 '*Orthis orthambonites* (Pander)' Billings: 77; non von Buch 1838, nec *O. calligramma* var. *orthambonites* de Verneuil in Murchison 1845.  
 cf. 1890 *Orthis orthambonites* "Pander sp." Billings; Schuchert: 43.  
 cf. 1892 *Orthis orthambonites* Billings, non von Buch; Hall & Clarke: 221.  
 cf. 1892 *Orthis panderiana* Hall & Clarke: pl. 5, footnote.  
 cf. 1894 *Orthis panderiana* Hall & Clarke; Hall & Clarke: 338.  
 cf. 1938 *Orthis panderiana* Hall & Clarke; Ulrich & Cooper: 102 (*cum syn.*)

DIAGNOSIS. Small, subquadrate to transversely ovate *Orthambonites*, with a moderately to strongly convex pedicle valve averaging 74% as long as wide and 46% as deep as long and a brachial valve averaging 70% as long as wide and 24% as deep as long; ornamented by 15–19 angular ribs with a wavelength of about one mm, 5 mm anteromedially of ventral umbo; ventral muscle field tripartite, with elongate median adductor scar extending anteriorly beyond flanking diductors.

DESCRIPTION. Small, subquadrate to transversely ovate, ventribiconvex *Orthambonites*; moderately to strongly convex pedicle valve averaging 74% as long as wide and 46% as deep as long ( $\bar{l}$  mm (var l) 4.41 (1.956),  $\bar{w}$  mm (var w) 6.00 (3.49),  $r = 0.931$ ;  $n = 22$ .  $\bar{l}$  mm (var l) 5.56 (0.736),  $\bar{th}$  mm (var th) 1.96 (0.276),  $r = 0.742$ ;  $n = 7$ ); brachial valve gently convex, averaging 70% as long as wide and 24% as deep as long ( $\bar{l}$  mm (var l) 3.67 (0.894),  $\bar{w}$  mm (var w) 5.18 (1.395),  $r = 0.916$ ;  $n = 21$ .  $\bar{l}$  mm (var l) 4.58 (0.564),  $\bar{th}$  mm (var th) 1.11 (0.036),  $r = 0.829$ ;  $n = 9$ ); lateral margins of both valves gently rounded, subparallel, anterior margins smoothly rounded or slightly truncated; external surfaces ornamented by 15–19 prominent angular ribs in 2, 9, 6, 6 and 2 brachial valves greater than 3 mm in length, with an average mean wavelength (and variance) of 0.96 mm (0.02) at 5 mm anteromedially of ventral umbones of 11 specimens; brachial valve with shallow, rounded sulcus, narrow posteriorly but becoming broader anteriorly and incorporating 3–6 ribs in 2, 12, 5 and 2 valves respectively; ventral interarea triangular, curved, apsacline, with open delthyrium, dorsal interarea narrow, anacline.

Ventral interior with flattened triangular teeth extending anteriorly on average for 18% of



**Figs 102–106** *Orthambonites cf. pandariana* (Hall & Clarke). Fig. 102a, b, BB 95372, dorsal and ventral views of conjoined valves, both  $\times 5$ ; Fig. 103, BB 95382, exterior of brachial valve,  $\times 5$ ; Fig. 104, BB 95373, interior of incomplete brachial valve,  $\times 5$ ; Fig. 105a, b, BB 95374, interior and oblique anterior view of incomplete pedicle valve, both  $\times 5$ ; Fig. 106a, b, BB 95450, interior and exterior of incomplete pedicle valve: a,  $\times 6$ ; b,  $\times 5$ .

**Figs 107–109** *Taphrorthis immatura* sp. nov. Fig. 107, holotype BB 95470, interior of incomplete brachial valve,  $\times 7$ ; Fig. 108a, b, paratype BB 95471, interior and exterior of pedicle valve, both  $\times 6$ ; Fig. 109a, b, paratype BB 95472, dorsal and ventral views of conjoined valves, both  $\times 6$ .



valve length ( $\bar{l}$  mm (var  $l$ ) 5.25 (0.717),  $\bar{l}_{tc}$  mm (var  $l_{tc}$ ) 0.93 (0.042),  $r = 0.767$ ;  $n = 11$ ), and supported by short, curved, receding, divergent dental plates; floor of pedicle valve with poorly-defined tripartite muscle attachment scars averaging 74% as wide as long ( $\bar{l}_{sc}$  mm (var  $l_{sc}$ ) 1.41 (0.167),  $\bar{w}_{sc}$  mm (var  $w_{sc}$ ) 1.05 (0.046),  $r = 0.908$ ;  $n = 8$ ), composed of elongate median adductor scar extending anteriorly beyond anterior margin of flanking elongate diductor scars or slightly elevated tongue-shaped platform.

Dorsal interior with ridge-like cardinal process, oblique sockets, and short, blunt, rod-like, divergent brachiophores with bases extending anteriorly on average 16% of brachial valve length ( $\bar{l}$  mm (var  $l$ ) 4.66 (0.621),  $\bar{l}_b$  mm (var  $l_b$ ) 0.74 (0.017),  $r = 0.636$ ;  $n = 11$ ) and 44% as long as the lateral extension of the sockets ( $\bar{l}_b$  mm (var  $l_b$ ) 0.74 (0.017),  $\bar{w}_{so}$  mm (var  $w_{so}$ ) 1.57 (0.080),  $r = 0.747$ ;  $n = 11$ ).

FIGURED MATERIAL.		length	width (mm)
Conjoined valves; BB 95372a, b		6.4	7.8
Incomplete pedicle valve; BB 95374		—	—
Incomplete pedicle valve; BB 95450		5.0	—
Brachial valve; BB 95382		4.5	6.6
Incomplete brachial valve; BB 95373		—	—

#### All Loc. 1.

DISCUSSION. Despite its cosmopolitan distribution throughout much of the Ordovician, *Orthambonites* displays a strong morphological conservatism, with many species virtually indistinguishable in terms of shell shape and proportions, and morphology of cardinalia. Only the maximum number of ribs developed in adult shells varies sufficiently to provide a ready means of distinguishing between different stocks of *Orthambonites*. In this respect the modal count of 16 ribs for the Tourmakeady specimens greatly restricts the number of species with which the Irish stock can be compared. Thereafter, the highly distinctive form of the ventral muscle field indicates a close morphological affinity with *O. pandariana* from Lower Ordovician successions in Quebec (see Ulrich & Cooper 1938: 102; the species was renamed by Hall & Clarke, 1892: footnote to description of pl. 5). The ventral muscle field of most *Orthambonites* is bilobed. That of *O. pandariana* (Ulrich & Cooper 1938: pl. 15A, fig. 3) is tripartite with an elongate median adductor scar extending anteriorly of the flanking diductors, and in every particular is identical with the muscle field of the Irish *Orthambonites*.

### Genus *TAPHRORTHIS* Cooper, 1956

#### *Taphrorthis immatura* sp. nov.

Figs 107–109

DIAGNOSIS. Medium-sized, subquadrate to transversely ovate or subcircular *Taphrorthis*, with a moderately to strongly convex pedicle valve averaging 69% as long as wide and 29% as deep as long, and a gently convex brachial valve averaging 65% as long as wide and 23% as deep as long; external ornamentation costellate, with 5–6 narrowly rounded ribs per mm at 2 mm anteromedially of dorsal umbo; ventral muscle field elongately oval, averaging 60% as wide as long.

NAME. 'Under-developed'.

DESCRIPTION. Medium-sized, subquadrate to transversely ovate or subcircular, ventribiconvex *Taphrorthis*; pedicle valve moderately to strongly convex, averaging 69% as long as wide (range 63–80%;  $n = 3$ ) and 29% as deep as long (range 25–31%;  $n = 3$ ); brachial valve gently convex, averaging 65% as long as wide (range 62–69%;  $n = 3$ ) and with a maximum thickness developed at sulcate anterior margin averaging 23% of valve length (range 23–24%;  $n = 3$ ); lateral margins of both valves strongly and smoothly rounded, anterior margin gently rounded with slight median emargination corresponding to brachial sulcus;



external ornamentation costellate with 5–6 narrowly rounded ribs per mm at 2 mm anteromedially of 3 and 1 brachial valves respectively, secondary costellae inserted in 3 generations; brachial valve with broad, shallow, rounded, sulcus; ventral interarea narrow, triangular, curved, apsacline, with open delthyrium, dorsal interarea very narrow, anacline.

Ventral interior with small, thickened, triangular teeth extending anteriorly for 20% of valve length in one specimen, and supported by strong, thickened, subparallel, dental plates with well-developed crural fossettes; floor of pedicle valve with elongately oval muscle platform with smoothly rounded, elevated, anterior rim, averaging 60% as wide as long (range 56–65%;  $n = 3$ ) and extending anteriorly for 35% and 33% of the length of two valves, muscle platform with poorly-developed median depression extending forward as a slightly elevated, smoothly rounded, medially depressed ridge running for 54% and 42% of the length of two adult valves.

Dorsal interior with short, thickened, spatulate, divergent brachiophores extending anteriorly for an average of 16% of valve length (range 13–20%;  $n = 3$ ), and flanked laterally by narrowly triangular, deeply incised sockets; notothyrial platform narrowly to broadly triangular, defined anteriorly by elevated, slightly curved margin and averaging 91% as long as wide (range 75–100%;  $n = 3$ ); cardinal process indistinct or as short, narrow ridge developed posteriorly on notothyrial platform; notothyrial platform buttressed medially by short, rounded ridge extending anteriorly for an average of 58% of valve length (range 54–64%;  $n = 3$ ).

HOLOTYPE. Incomplete brachial valve; BB 95470. Fig. 107.

	length	width (mm)
PARATYPES. Conjoined valves; BB 95472a, b	3.6	5.7
Pedicle valve; BB 95471	5.1	7.8
Incomplete pedicle valve; BB 95473	—	—
Brachial valve; BB 95474	4.7	7.4

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. *Taphrorthis* is rare in the Tourmakeady Limestone, and a high proportion of the recovered specimens have been deformed. As a result detailed measurements of shell parameters are unavailable, but there are sufficient data from the few complete, undeformed, specimens to allow comparison with previously-described species of the genus. In the original diagnosis of the genus, Cooper (1956: 326) stated that *Taphrorthis* is characterized by the presence of a cardinal process, albeit one which was often poorly developed. In contrast, two of the three brachial valves in the Tourmakeady sample bore no discernible cardinal process, although the third did possess a short structure consistent with Cooper's description of a 'low inconspicuous ridge'. On balance, the fact that an undifferentiated cardinal process is not discernible in the majority of brachial valves cannot be considered sufficient to justify the exclusion of the sample from *Taphrorthis*. In all other respects the sample conforms to Cooper's diagnosis for the genus, and the Irish species being significantly older than other species so far assigned to the genus suggests that the poor development of the cardinal process is a primitive feature.

The sporadic development of an undifferentiated cardinal process is not the only distinguishing feature of the Irish *Taphrorthis* calling for its specific recognition. The main features characterizing described species of *Taphrorthis* are the shape of the ventral muscle scar and the details of the external ornamentation. In these respects the presence of an elongately ovate ventral platform with a poorly-developed median depression and a relatively fine ornamentation further distinguish the Irish specimens. *T. emarginata* Cooper (1956: 327), the type species of the genus from the Middle Ordovician of Alabama and Tennessee, has a prominent median ridge bisecting the ventral muscle platform and 10 ribs per 5 mm anteromedially; the comparable figure for *T. immatura* is 20–21 ribs per 5 mm. In addition figured specimens of *T. emarginata* display a cardinal process running the entire length of the notothyrial platform; when developed in *T. immatura*, the cardinal process is

only discernible at the posterior margin of the notothyrial platform. *T. peculiaris* Cooper (1956: 328), also from the Middle Ordovician of North America, can again be distinguished from the new species by its anteriorly bilobed ventral muscle platform and coarser ornamentation numbering 12 ribs per 5 mm anteromedially.

*Taphrorthis* has also been recorded previously from Britain, but comparisons based primarily on the shape of the ventral muscle field and on the external ornamentation confirm the distinctiveness of the new species. Thus the ventral muscle field of *T. aspera* Williams (1962: 102), from the Caradoc of the Girvan District, is strongly trilobed anteriorly and has about 10 ribs per 5 mm anteromedially. Similarly *T. bellatrix* (Reed), also from the Caradoc of the Girvan District (Williams 1962: 103), is readily distinguishable from *T. immatura* by its readily discernible cardinal process, its medially divided ventral muscle field, and its coarser ornamentation, with 10 ribs per 5 mm anteromedially, which bears radial striae and is crossed by concentric lamellae.

### Family DOLERORTHIDAE Öpik, 1934

#### Subfamily GLYPTORTHINAE Schuchert & Cooper, 1931

#### Genus LOMATORTHIS nov.

DIAGNOSIS. Large, biconvex, semicircular to subquadrate glyptorthine with flattened or gently resupinate lateral and anterior margins; external ornamentation costellate, crossed by well-developed concentric growth-lines becoming strongly lamellose peripherally and elevated above shell surface as erect frills; ventral interarea gently curved, apsacline, with narrowly triangular, open delthyrium; dorsal interarea narrow, triangular, anacline, notothyrium open.

Ventral interior with small, triangular, teeth supported by short, receding, divergent dental plates; adductor muscle scars elevated on triangular, posteriorly-tapering, platform, flanked posterolaterally by elongate, concave, diductor muscle scars impressed on valve floor and constrained laterally by dental plates; ventral mantle canal system saccate (?).

Dorsal interior with short, blade-like divergent brachiophores flanking undifferentiated notothyrial platform; adductor scars quadripartite, mantle canal system possibly digitate.

NAME. Greek, *λῶμα*, the hem of a garment.

TYPE SPECIES. *Lomatorthis mimula* sp. nov., from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The combination of well-developed dorsal and ventral interareas, open delthyrium and notothyrium, and strong concentric lamellar ornamentation establishes *Lomatorthis* as a representative of the Glyptorthinae. Of those genera presently assigned to that subfamily, the majority can readily be distinguished from the new genus because they possess a prominent cardinal process (e.g. *Glyptorthis* Foerste; *Ptychopleurella* Schuchert & Cooper). In addition, both *Glyptorthis* and *Ptychopleurella* differ in being strongly sulcate, while *Eridorthis* Foerste is uniplicate. *Spinorthis* Wright also possesses a well-developed cardinal process, and can further be distinguished from the new genus by the presence of spinose extensions along the external concentric lamellae.

Among described glyptorthins, *Lomatorthis* is closest to *Lepidorthis* Wang, especially in external form; but there are significant differences internally, especially in the morphology of the cardinalia and disposition of ventral muscle scars, which confirm the distinction between the two genera. In the original diagnosis, *Lepidorthis* is described as lacking a cardinal process (Wang 1955: 330). However, illustrations of the type material reveal a low, rounded, median ridge in the floor of the notothyrial cavity of both brachial valves figured, which is undoubtedly an undifferentiated cardinal process. Such a feature is not evident in any of the Tourmakeady specimens. Moreover, the dorsal interarea of *Lepidorthis* is much narrower than that of *Lomatorthis*, and the dental plates are proportionately much larger. Furthermore, the brachiophores in *Lepidorthis* are strongly thickened, massive, and curved; in

*Lomatorthis* they are small, delicate and straight. The pattern of muscle attachment in the pedicle valve especially distinguishes the two genera. In *Lepidorthis* the ventral muscle field is undifferentiated and confined to the posterior slope of the median callus. In *Lomatorthis*, the comparable region represents the site of adductor muscle attachment, and is clearly differentiated in all specimens from the flanking, elongate diductor scars.

The distinctive association of morphological features diagnostic of *Lomatorthis* has not been recorded previously in the literature, and for the present the Tourmakeady species remains the sole representative of the new genus.

*Lomatorthis mimula* sp. nov.

Figs 110–116

**DIAGNOSIS.** Large, thick-shelled, semicircular to subquadrate *Lomatorthis*, on average 55% as long as wide; external ornamentation of approximately 10 rounded costellae in a 5 mm sector 5 mm anteromedially of umbo, crossed by strong lamellose concentric growth-lines elevated into erect frills extending up to 0.7 mm above valve surface.

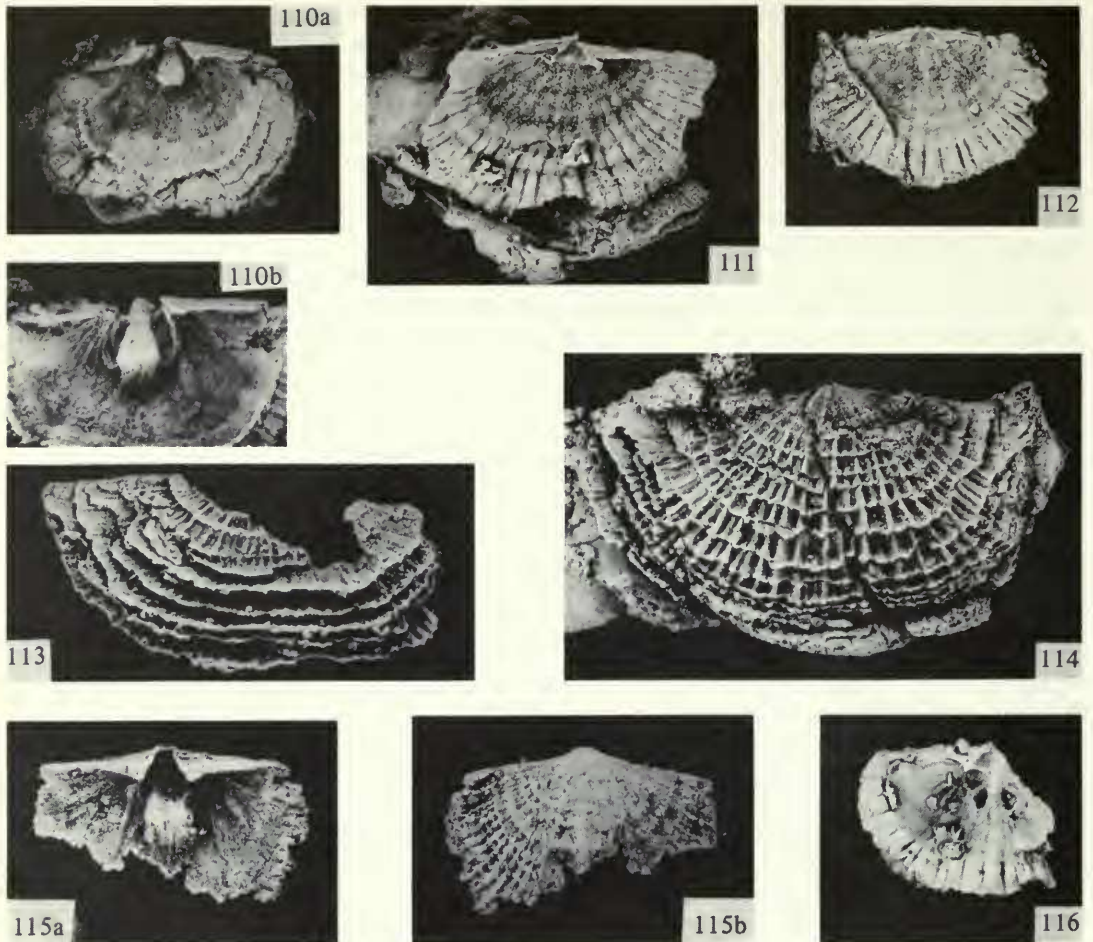
**NAME.** 'Child actress'.

**DESCRIPTION.** Large, thick-shelled, semicircular to subquadrate *Lomatorthis*, on average 55% as long as wide (1 mm (var l) 4.3 (3.21),  $\bar{w}$  mm (var w) 7.89 (9.41),  $r = 0.933$ ;  $n = 41$ ) and attaining a maximum width of 22 mm, both valves strongly to moderately convex, on average 29% as deep as wide (range 28–30% in 3 specimens), with flattened or gently resupinate submarginal platform along smoothly rounded, rectimarginate, anterior and lateral margins; external radial ornamentation costellate, with on average 10 (range 7–12) rounded ribs in a 5 mm sector at 5 mm anteromedially of umbo, with new ribs developed by intercalation when wavelength of existing ribs exceeds 0.6 mm; concentric growth-lines well developed, becoming strongly lamellose peripherally and elevated into erect, concentric frills extending at least 0.7 mm above valve surface; triangular ventral interarea gently curved, aplanate, grooved by well-developed growth-lines, delthyrium large, triangular, open, on average 85% (range 79–93%) as wide as long in 4 specimens; dorsal interarea anacline, narrowly triangular, with broad, triangular, open notothyrium.

Ventral interior with small, flattened, triangular teeth supported by posteriorly tapering, short, receding, divergent dental plates; adductor muscle scars elevated on prominent platform of variable proportions but posteriorly tapering and averaging 89% as wide as long in 4 specimens (range 80–100%), with a maximum elevation, developed anteriorly, on average 63% as high as long (range 52–80%) in 4 specimens, posterior slope of platform marked by anteriorly convex growth-lines; adductor platform flanked laterally by elongate, concave, diductor scars, on average 35% as wide as long in 3 specimens (range 29–40%), defined posterolaterally by inner wall of dental plates, and with slightly elevated, strongly convex, anterior margin extending anteriorly on average 71% of the length of adductor platform (range 66–80%); ventral mantle canal system saccate (?), with two narrow branches of *vascula media* faintly impressed immediately anteriorly of platform but dying out anteriorly, and up to four narrow canals of *vascula genitalia* impressed posterolaterally of adductor platform and dying out peripherally.

Dorsal interior with triangular, gently concave, undivided notothyrial platform, on average 62% as long as wide in 3 specimens (range 47–65%); brachiophores short, simple, divergent, blade-like, lying within plane of dorsal interarea, extending forward for an average of 13% (range 13–14%) of the length of 3 brachial valves, and posterolaterally defining small, triangular, sockets; two pairs of ovate adductor scars strongly impressed immediately anterior of notothyrial cavity symmetrically on either side of short, low median ridge, posterior pair transversely oval in outline, with long axis diverging anteriorly at 70° to median axis of valve, and measuring 1 × 0.5 mm in one valve, anterior pair of adductor scars subparallel with median axis of valve, and measuring 1.4 × 0.9 mm in one valve; 3–4 short





**Figs 110–116** *Lomatorthis mimula* gen. et sp. nov. Fig. 110a, b, **holotype** BB 95360, interior and oblique anterior views of incomplete pedicle valve: a,  $\times 2$ ; b,  $\times 3$ ; Fig. 111, paratype BB 95366, interior of incomplete brachial valve,  $\times 4$ ; Fig. 112, paratype BB 95364, interior of brachial valve,  $\times 3$ ; Fig. 113, paratype BB 95361, exterior of incomplete brachial valve,  $\times 3$ ; Fig. 114, paratype BB 95362, exterior of brachial valve,  $\times 3$ ; Fig. 115a, b, paratype BB 95365, interior and exterior of incomplete pedicle valve,  $\times 3$ ; Fig. 116, paratype BB 95363, interior of incomplete brachial valve,  $\times 3$ .

branches of dorsal mantle canal system of possibly digitate pattern impressed posterolaterally of adductor scars but dying out laterally.

**HOLOTYPE.** Incomplete pedicle valve; BB 95360. Fig. 110.

PARATYPES.		length	width (mm)
Incomplete pedicle valve; BB 95365		—	—
Brachial valve; BB 95362		11.0	19.8
Brachial valve; BB 95364		8.0	10.8
Incomplete brachial valve; BB 95361		—	—
Incomplete brachial valve; BB 95363		6.6	—
Incomplete brachial valve; BB 95366		—	—

**TYPE HORIZON AND LOCALITY.** Loc. 1.

## Family FINKELNBURGIIDAE Schuchert &amp; Cooper, 1931

Genus *NOTOSCAPHIDIA* nov.

DIAGNOSIS. Small, moderately to strongly transversely oval finkelnburgiid, pedicle valve strongly convex with prominent, tapering umbo, brachial valve strongly convex postero-medially, becoming gently convex peripherally; external ornamentation coarsely costellate; ventral interarea broad, gently curved, apsacline, with open delthyrium; dorsal interarea narrowly triangular, anacline, notothyrium open.

Ventral interior with small triangular teeth supported by short, receding, slightly divergent, dental plates forming lateral margins of transversely ovate pseudospondylium, predominantly sessile but becoming free along anterior and anterolateral margins; ventral mantle canal impressions unknown.

Dorsal interior with short, erect brachiophores flanked laterally by deeply incised sockets defined by fulcral plates, and supported by strong, inclined, anteriorly rounded brachiophore bases discrete in juvenile specimens but converging medially in later growth stages to form broadly triangular notothyrial platform with bilobed anterior margin; dorsal adductor muscle scars quadripartite, strongly impressed symmetrically on either side of median ridge; mantle canal system in dorsal valve unknown.

NAME. Greek, *νώτος*, the back, + *σκαφίδιον*, a small boat.

TYPE SPECIES. *Notoscaphidia revelata* sp. nov., from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The combination of a ventral pseudospondylium and short, erect brachiophores flanked by fulcral plates and supported by well-developed inclined brachiophore bases establishes *Notoscaphidia* as a representative of the Finkelnburgiidae. The most distinctive feature of the new genus, which immediately distinguishes it from all other finkelnburgiid genera, is the form of the dorsal cardinalia. Although the earliest growth stages have not been recovered, the Tourmakeady residues contained a sufficient size-range of specimens to allow the growth pattern of the cardinalia to be determined in at least the later stages. In the smallest brachial valve available, slightly less than 2 mm in length, the brachiophores are well-developed and are flanked by deeply incised sockets defined by fulcral plates which are only barely elevated above the valve floor. Laterally the brachiophores are supported by well-developed, anteriorly rounded, brachiophore bases which slope down to the valve floor at a low angle and unite with the posterior regions of the median ridge which is well-developed in even the smallest specimens examined. Subsequent growth results in the thickening and elevation of the fulcral plates above the valve floor, and the coalescence of the brachiophore bases to form a strongly concave, anteriorly bilobed, notothyrial platform with a more or less well defined median suture.

In contrast, the notothyrial platform in other finkelnburgiid genera, such as *Finkelnburgia* Walcott and *Fasciculina* Cooper, shows no signs of anterior bilobation, and has a linear to slightly curvate anterior margin defined by discrete, inclined, brachiophore bases united with the median ridge. In addition both *Finkelnburgia* and *Fasciculina* differ from the new genus in having well-developed cardinal processes. *Fasciculina* also differs in having a coarsely fascicostellate ornamentation. Similarly both *Orusia* Walcott and *Diparelasma* Ulrich & Cooper can readily be distinguished from *Notoscaphidia* on the basis of cardinal morphology, as the brachiophore bases in both genera remain discrete throughout ontogeny. *Orusia* can further be distinguished by the lack of pseudospondylium in the ventral valve.

Although the pattern of cardinalia development in *Notoscaphidia* is diagnostic, familial relationship with the other finkelnburgiids is evident. In all genera assigned to the family the brachiophore bases are either subparallel or convergent, but in any event unite with the valve floor (or median ridge) to form the anterior margin of the notothyrial platform. This arrangement represents the maximum development attained by adults of genera such as *Fasciculina* and *Finkelnburgia*, in which the notothyrial platform remains small throughout ontogeny. The comparable arrangement in *Notoscaphidia* represents an intermediate stage in



cardinalia development and the brachiophore bases continue to grow both laterally and anteriorly to form a relatively large notothyrial platform.

In many respects the later stages of cardinalia development in *Notoscaphidia* are identical to those recognized in the skenidiid genus *Protoskenidioides* (Williams 1974: 83). In the latter genus, however, the coalescence of the brachiophore bases was usually accompanied by the development of a prominent cardinal process. Furthermore, despite the similarity in the form of the dorsal cardinalia, all skenidiids, including *Protoskenidioides*, can readily be distinguished from the finkelnburgiids in that they have a free or supported spondylium in the pedicle valve while the latter are characterized by a pseudospondylium (the only exception being *Orusia* which lacks both structures). Nevertheless the similarity in the pattern of development between *Protoskenidioides* and *Notoscaphidia* adds further weight to the suggestion that the finkelnburgiids formed the ancestral stock from which the skenidiids developed (Kozłowski 1929, Williams 1974: 85). *Protoskenidioides* was first described from the Upper Arenig Mytton Flags of Shropshire, and was thought to have been ancestral to the very successful genus *Skenidioides* which survived from the Lower Ordovician to the Upper Silurian (Williams 1974: 85). The discovery of both *Protoskenidioides* and a new finkelnburgiid genus in the Tourmakeady Limestone suggests that the skenidiids developed from an ancestral finkelnburgiid stock in the uppermost Cambrian or lowermost Ordovician. The derived skenidiids, the evolution of which was characterized primarily by the development of a spondylium, survived until the Devonian. The ancestral finkelnburgiids, in contrast, never developed a spondylium, and became extinct in the Middle Ordovician.

At present *Notoscaphidia revelata* is the sole known representative of the genus.

### *Notoscaphidia revelata* sp. nov.

Figs 117–123

**DIAGNOSIS.** Small, moderately to strongly transversely oval *Notoscaphidia* with a pedicle valve averaging 71% as long as wide and 46% as deep as long, and a brachial valve averaging 65% as long as wide and 40% as deep as long; external ornamentation coarsely costellate with an average of 6 ribs per mm at 2 mm anteromedially of dorsal umbo.

**NAME.** 'Uncovered'.

**DESCRIPTION.** Small, moderately to strongly transversely oval *Notoscaphidia*; strongly convex pedicle valve averaging 71% as long as wide ( $\bar{l}$  mm (var l) 2.63 (0.056),  $\bar{w}$  mm (var w) 3.71 (0.233),  $r = 0.845$ ;  $n = 8$ ) and with a maximum thickness averaging 46% of valve length developed posteriorly at prominent, tapering, umbo ( $\bar{l}$  mm (var l) 2.63 (0.056),  $\bar{th}$  mm (var th) 1.20 (0.023),  $r = 0.796$ ;  $n = 8$ ); brachial valve strongly convex posteromedially becoming gently convex peripherally and averaging 65% as long as wide ( $\bar{l}$  mm (var l) 2.54 (0.172),  $\bar{w}$  mm (var w) 3.88 (0.086),  $r = 0.747$ ;  $n = 10$ ) and with a maximum thickness developed at sulcate anterior margin averaging 40% of valve length ( $\bar{l}$  mm (var l) 2.61 (0.183),  $\bar{th}$  mm (var th) 1.16 (0.018),  $r = 0.835$ ;  $n = 10$ ), lateral margins of both valves smoothly rounded, anterior margin with variably gently rounded dorsal sulcus; external ornamentation coarsely costellate with 5–8 rounded ribs per mm at 2 mm anteromedially of the umbones of 2, 7, 2 and 1 brachial valves respectively; ventral interarea broad, apsacline, curved, with open delthyrium, dorsal interarea narrow, curved, anacline.

Ventral interior with small, thickened, triangular teeth supported by short, receding, divergent, dental plates forming lateral margins of anteriorly-rounded, transversely ovate pseudospondylium with free anterior and anterolateral margins and averaging 87% as long as wide ( $\bar{l}_p$  mm (var  $l_p$ ) 0.74 (0.014),  $\bar{w}_p$  mm (var  $w_p$ ) 0.85 (0.009);  $r = 0.844$ ;  $n = 8$ ).

Dorsal interior with thickened, erect brachiophores flanked by narrow, deeply incised, triangular sockets defined by well-developed, thickened, fulcral plates; brachiophores





**Figs 117–123** *Notoscaphtidia revelata* gen. et sp. nov. Fig. 117, **holotype** BB 95476, interior of brachial valve,  $\times 8$ ; Fig. 118, paratype BB 95484, interior of brachial valve,  $\times 8$ ; Fig. 119, paratype BB 95483, dorsal view of conjoined valves,  $\times 4$ ; Fig. 120, paratype BB 95481, dorsal view of conjoined valves,  $\times 8$ ; Fig. 121, paratype BB 95477, interior of incomplete pedicle valve,  $\times 8$ ; Fig. 122, paratype BB 95480, interior of incomplete pedicle valve,  $\times 4$ ; Fig. 123, paratype BB 95479, interior of brachial valve,  $\times 12$ .

supported by strong, anteriorly rounded, discrete brachiophore bases united with median ridge in early growth stages but becoming conjoined in adult specimens to form broadly triangular, strongly concave, anteriorly bilobed, notothyrial platform sutured medially and extending anteriorly for an average of 24% of valve length ( $\bar{l}$  mm (var  $l$ ) 2.78 (0.067),  $\bar{l}_n$  (var  $l_n$ ) 0.66 (0.008),  $r = 0.753$ ;  $n = 8$ ), and averaging 95% as long as wide ( $\bar{l}_n$  mm (var  $l_n$ ) 0.66 (0.008),  $\bar{w}_n$  mm (var  $w_n$ ) 0.63 (0.005),  $r = 0.768$ ;  $n = 9$ ); floor of valve with long, low, rounded, median ridge extending anteriorly from beneath elevated anterior margin of notothyrial platform for an average of 67% of valve length ( $\bar{l}$  mm (var  $l$ ) 2.75 (0.085),  $\bar{l}_s$  mm (var  $l_s$ ) 1.84 (0.086),  $r = 0.763$ ;  $n = 10$ ); two pairs of elongately suboval adductor muscle scars impressed strongly on either side of median ridge, and clearly defined by fine elevated rims of shell, posteriormost pair impressed anterolaterally of notothyrial platform with longitudinal axis diverging anteriorly at  $60^\circ$  with median axis of valve and averaging 59% as wide as long (range 50–67%;  $n = 5$ ); anterior pair impressed anteromedially of posterior pair, flanking, and with longitudinal axis parallel to, median ridge, and averaging 52% as wide as long (range 50–56%;  $n = 5$ ).

**HOLOTYPE.** Brachial valve; BB 95476: length 3.0 mm, width 4.6 mm. Fig. 117.

PARATYPES.		length	width (mm)
Conjoined valves; BB 95478a, b		2.9	3.8
Conjoined valves; BB 95481a, b		2.6	3.8
Conjoined valves; BB 95483a, b		2.6	4.0
Incomplete pedicle valve; BB 95477		–	4.6
Incomplete pedicle valve; BB 95480		–	–
Incomplete pedicle valve; BB 95482		–	–
Brachial valve; BB 95479		1.8	2.8
Incomplete brachial valve; BB 95484		3.0	–

**TYPE HORIZON AND LOCALITY.** Loc. 1.

**DISCUSSION.** Judged on the statistical analyses of its chief features, *Notoscaphtidia revelata* is a morphologically variable species by orthacean standards.

Family **CREMNORTHIDAE** Williams, 1963  
 Subfamily **PHRAGMORTHINAE** Williams, 1965  
 Genus **PHRAGMORTHIS** Cooper, 1956  
*Phragmorthis mucronata* sp. nov.

Figs 124–129

**DIAGNOSIS.** Small, ventribiconvex, strongly mucronate *Phragmorthis*; moderately to strongly convex pedicle valve 42% as long as wide and 65% as deep as long; brachial valve moderately convex averaging 49% as long as wide and 36% as deep as long; external ornamentation multicostellate with 6–8 rounded ribs per mm at 1 mm anteromedially of dorsal umbo; dorsal interior with long, low, rounded median septum extending for an average of 81% of valve length.

**NAME.** 'Sharply pointed'.

**DESCRIPTION.** Small, ventribiconvex, strongly mucronate *Phragmorthis*; moderately to strongly convex pedicle valve averaging 42% as long as wide ( $\bar{l}$  mm (var l) 1.62 (0.082),  $\bar{w}$  mm (var w) 3.80 (0.170),  $r = 0.932$ ;  $n = 9$ ) and 65% as deep as long ( $\bar{l}$  mm (var l) 1.62 (0.082),  $\bar{th}$  mm (var th) 1.03 (0.020),  $r = 0.690$ ;  $n = 9$ ); brachial valve gently convex averaging 49% as long as wide (range 43–55%;  $n = 4$ ) and 36% as deep as long (range 31–42%;  $n = 3$ ); lateral margins of both valves gently rounded, anterior margins strongly rounded, and bilobed by smoothly rounded dorsal median sulcus narrow posteriorly but becoming wider anteriorly; external ornamentation multicostellate with 6–8 rounded ribs per mm at 1 mm anteromedially of the umbones of 6, 2 and 1 brachial valves respectively, new ribs inserted by interior bifurcation of swollen primary costa to give standard ribbing pattern of  $1\bar{a}$ , 1,  $2\bar{a}$ , 2,  $3\bar{a}$ , 3, etc. with  $1\bar{a} > 2\bar{a} > 3\bar{a}$ ; ventral interarea broadly triangular, gently curved, apsacline, with open delthyrium, dorsal interarea narrow, anacline.

Ventral interior with thickened triangular teeth supported by small receding dental plates, posteriorly flanking undifferentiated, elevated, transversely oval muscle attachment platform on average 55% as long as wide ( $\bar{l}_{sc}$  mm (var  $l_{sc}$ ) 0.45 (0.017),  $\bar{w}_{sc}$  mm (var  $w_{sc}$ ) 0.83 (0.036),  $r = 0.915$ ;  $n = 8$ ).

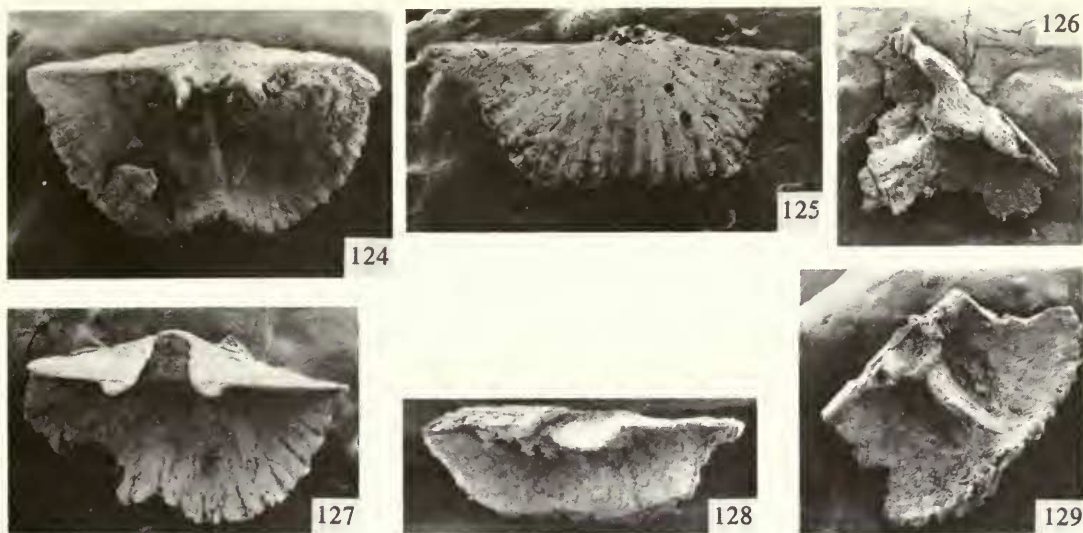
Dorsal interior with long, narrow, suberect, tapering brachiophores, confined to plane of dorsal interarea and extending up to 0.7 mm above valve floor in two specimens, flanked laterally by broad triangular sockets defined anterolaterally by well-developed, elevated, concave, fulcral plates; thickened brachiophore bases unite medially on floor of valve to form elevated, anteriorly tapering, anterior margin of broadly triangular septalium measuring  $0.6 \times 0.6$  mm and  $0.5 \times 0.5$  mm in 2 and 1 brachial valves respectively; floor of valve with long, low, rounded median septum extending anteriorly from anterior margin of septalium for an average of 82% (range 81–84%;  $n = 3$ ) of valve length; median septum flanked laterally by pair of elongately oval adductor muscle scars with strongly elevated crescentic lateral margins, averaging 50% as wide as long in three specimens (range 44–56%).

**HOLOTYPE.** Brachial valve; BB 95457: length 2.0 mm, width 3.9 mm. Fig. 124.

		length	width (mm)
PARATYPES.	Conjoined valves; BB 95459a, b	1.9	4.6
	Pedicle valve; BB 95602	1.2	3.3
	Incomplete pedicle valve; BB 95458	–	–
	Incomplete brachial valve; BB 95460	1.9	–
	Incomplete brachial valve; BB 95603	–	–

**TYPE HORIZON AND LOCALITY.** Loc. 1.

**DISCUSSION.** The Tourmakeady residues contained a small number of specimens of a species



**Figs 124–129** *Phragmorthis mucronata* sp. nov. Fig. 124, **holotype** BB 95457, interior of brachial valve,  $\times 12$ ; Fig. 125, paratype BB 95459, dorsal view of conjoined valves,  $\times 11$ ; Fig. 126, paratype BB 95603, interior of incomplete brachial valve,  $\times 12$ ; Fig. 127, paratype BB 95458, interior of incomplete pedicle valve,  $\times 12$ ; Fig. 128, paratype BB 95602, interior of pedicle valve,  $\times 12$ ; Fig. 129, paratype BB 95460, interior of incomplete brachial valve,  $\times 12$ .

reminiscent in external form of some skenidiid genera, but unequivocally assignable to the cremnorthid genus *Phragmorthis* on the basis of its sessile muscle platform in the pedicle valve.

The Irish stock could not readily be confused with any of the few previously-described species of *Phragmorthis*. *P. buttsi* Cooper, the type species, and *P. crassa*, both from the Middle Ordovician of North America (Cooper 1956: 510), are readily distinguishable even in external form, as they have a rounded, non-mucronate outline and are proportionately much more elongate than the Irish representatives. *P. mucronata* is also distinguishable internally in having a much lower median septum and a much more transverse ventral muscle platform.

#### Family SKENIDIIDAE Kozłowski, 1929

##### Genus *CROSSISKENIDIUM* nov.

**DIAGNOSIS.** Small, moderately to strongly transversely oval skenidiid; pedicle valve moderately convex with prominent rounded umbo; brachial valve shallowly to moderately convex with narrow, smoothly rounded sulcus; external ornamentation finely multicostellate with numerous, closely-spaced, concentric growth-lines elevated as thin peripheral flanges bearing a row of flat, anteriorly rounded, spinose projections; ventral interarea broad, curved, apsacline, with open delthyrium, dorsal interarea narrowly triangular, gently curved, anacline, notothyrium open.

Ventral interior with small triangular teeth supported by short, receding, slightly divergent dental plates forming lateral margins of semicircular spondylium, strongly rounded anteriorly and sessile posteriorly but becoming free anteriorly and anterolaterally; ventral mantle canal system unknown.

Dorsal interior with prominent, erect, tapering brachiophores flanked laterally by shallow sockets defined by thin fulcral plates and supported by strong, thickened, inclined, brachiophore bases sloping down to valve floor to unite with posterior region of long, low,



rounded, median ridge; notothyrial platform strongly concave, with tapering triangular anterior margin; adductor muscle scars impressed symmetrically on either side of median ridge as pair of elongately oval areas defined by elevated, smoothly rounded, rim of shell; dorsal mantle canal system unknown.

NAME. Greek, *κροσσωτός*, fringed.

TYPE SPECIES. *Crossiskenidium spinosum* sp. nov. from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The Tourmakeady residues contained a small number of minute brachiopods with an internal morphology indicating skenidiid affinities but with a distinctive external ornamentation not previously recorded in this family. Thus the prominent, erect, brachiophores supported by well-developed, coalescing, brachiophore bases in the brachial valve, combined with a spondylium in the pedicle valve, are diagnostic of the skenidiids. Externally, the spiny lamellose ornamentation of *Crossiskenidium* is so distinctive as to distinguish it immediately from all genera at present assigned to the family.

*Crossiskenidium* is presently known only from the Tourmakeady Limestone, which also contains a few specimens provisionally identified as a second species of the new genus.

### *Crossiskenidium spinosum* sp. nov.

Figs 130–139

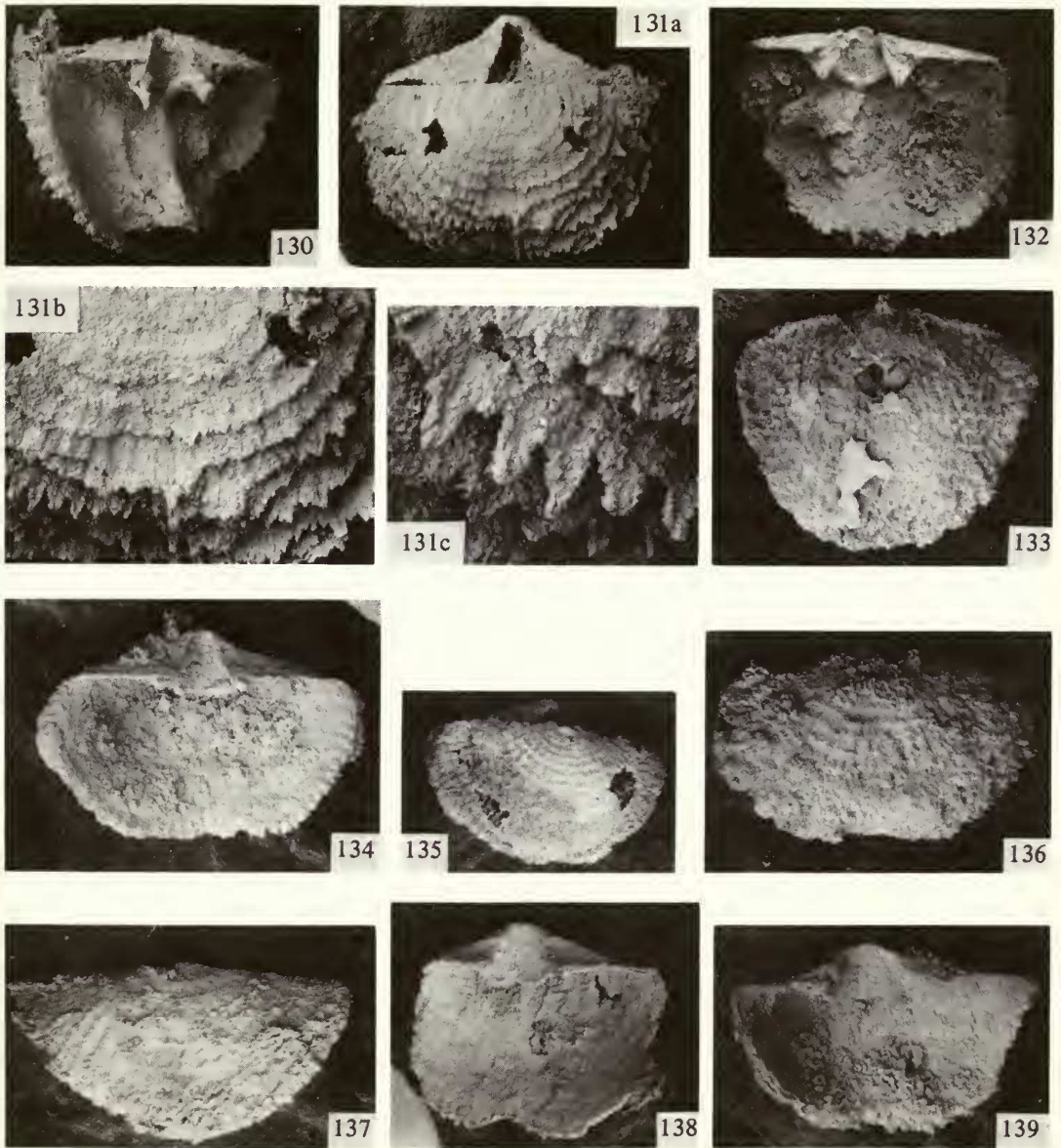
DIAGNOSIS. Small, moderately to strongly oval *Crossiskenidium*; moderately convex pedicle valve averaging 63% as long as wide and 46% as deep as long; shallowly to moderately convex brachial valve averaging 58% as long as wide and 37% as deep as long; external ornamentation finely multicostellate with an average of 10 rounded ribs per mm at 2 mm anteromedially of dorsal umbo crossed by up to 12 closely-spaced, lamellose growth-lines each bearing a row of flat, anteriorly-rounded, peripheral spines.

NAME. 'Spiny'.

DESCRIPTION. Small, moderately to strongly transversely oval *Crossiskenidium*, moderately convex pedicle valve averaging 63% as long as wide (range 57–74%;  $n = 5$ ) and with a maximum thickness developed at prominent, rounded, ventral umbo averaging 46% of valve length (range 35–52%;  $n = 5$ ), shallowly to moderately convex brachial valve averaging 58% as long as wide (range 50–74%;  $n = 5$ ) and with a maximum thickness developed at sulcate anterior margin averaging 37% of valve length (range 28–47%;  $n = 5$ ); lateral margins of both valves gently convex, anterior margins strongly convex with shallow, rounded, dorsal sulcus with an average width of 0.8 mm at 2 mm anteromedially of the dorsal umbo of 3 valves (range 0.8–0.9 mm); external ornamentation finely multicostellate with an average of 10 (range 10–11;  $n = 3$ ) rounded ribs per mm at 2 mm anteromedially of dorsal umbo, ribs crossed by closely-spaced, lamellose growth-lines, up to 12 per adult shell, elevated above the valve surface as short flanges extending peripherally as a row of short, flattened, anteriorly-rounded spines.

Ventral interior with small triangular teeth supported by short, receding, divergent dental plates forming lateral margin of anteriorly-rounded, transversely ovate spondylium elevated anteriorly and anterolaterally but sessile posteriorly and extending anteriorly for an average of 33% of valve length (range 30–35%;  $n = 2$ ) and averaging 73% as long as wide (range 70–78%;  $n = 3$ ).

Dorsal interior with prominent, erect brachiophores extending for 1.1 mm and 1.2 mm above valve floor in two adult specimens, and flanked by shallow, narrowly triangular sockets defined by thin fulcral plates; brachiophores supported by strong, inclined brachiophore bases united medially with median ridge to define strongly concave, narrowly triangular, notothyrial platform with tapering triangular anterior margin and averaging 79% as wide as long (range 71–83%;  $n = 3$ ); floor of valve with long, low, rounded median ridge



**Figs 130–139** *Crossiskenidium spinosum* gen. et sp. nov. Fig. 130, holotype BB 95485, interior of incomplete brachial valve,  $\times 14$ ; Fig. 131a, b, c, paratype BB 95490, dorsal view of conjoined valves: a,  $\times 13$ ; b, detail,  $\times 26$ ; c, detail,  $\times 80$ ; Fig. 132, paratype BB 95494, interior of incomplete brachial valve,  $\times 13$ ; Fig. 133, paratype BB 95491, exterior of incomplete brachial valve,  $\times 18$ ; Fig. 134, paratype BB 95486, interior of pedicle valve,  $\times 12$ ; Fig. 135, paratype BB 95487, dorsal view of conjoined valves,  $\times 8$ ; Fig. 136, paratype BB 95493, dorsal view of conjoined valves,  $\times 10$ ; Fig. 137, paratype BB 95488, exterior of brachial valve,  $\times 13$ ; Fig. 138, paratype BB 95489, interior of incomplete pedicle valve,  $\times 14$ ; Fig. 139, paratype BB 95492, interior of pedicle valve,  $\times 13$ .



flanked by pair of smoothly rounded, elongately oval muscle scars defined by prominent elevated rim of shell and measuring  $0.1 \times 0.5$  mm in one specimen.

HOLOTYPE. Incomplete brachial valve; BB 95485. Fig. 130.

		length	width (mm)
PARATYPES.	Conjoined valves; BB 95487a, b	2.6	4.2
	Conjoined valves; BB 95490a, b	2.5	3.4
	Conjoined valves; BB 95493a, b	2.6	3.6
	Pedicle valve; BB 95486	2.3	3.5
	Pedicle valve; BB 95492	1.9	3.2
	Incomplete pedicle valve; BB 95489	—	—
	Brachial valve; BB 95488	1.9	3.6
	Brachial valve; BB 95491	2.6	3.3
	Incomplete brachial valve; BB 95494	—	—

TYPE HORIZON AND LOCALITY. Loc 1.

*Crossiskenidium? lamellosum* sp. nov.

Figs 140–146

DIAGNOSIS. Minute, transversely ovate skeniid; moderately convex pedicle valve averaging 51% as long as wide and 56% as deep as long; moderately and smoothly convex brachial valve averaging 44% as long as wide and 62% as deep as long; external ornamentation finely and evenly multicostellate with 15–16 rounded ribs per mm at one mm anteromedially of dorsal umbo, crossed by well-developed lamellose, concentric growth-lines extending as prominent peripheral flanges.

NAME. 'With lamellae'.

DESCRIPTION. Minute, transversely ovate skeniidiids; moderately convex pedicle valve averaging 51% as long as wide (range 46–55%;  $n = 5$ ) and with a maximum thickness at strongly rounded umbo averaging 56% of valve length (range 47–64%;  $n = 4$ ); brachial valve moderately and smoothly convex averaging 44% (range 43–45%;  $n = 2$ ) as long as wide and with a maximum thickness developed at strongly sulcate anterior margin averaging 62% of valve length (range 56–67%;  $n = 2$ ); lateral margins of both valves smoothly rounded, anterior margin bilobed by prominent, rounded, dorsal median sulcus; external ornamentation finely and evenly multicostellate with 15–16 rounded ribs per mm at one mm anteromedially of the umbones of 2 and 3 brachial valves respectively; ribs crossed by well-developed concentric growth-lines becoming strongly lamellose in adult growth stages and extending peripherally beyond valve margins for up to 0.7 mm as prominent flanges.

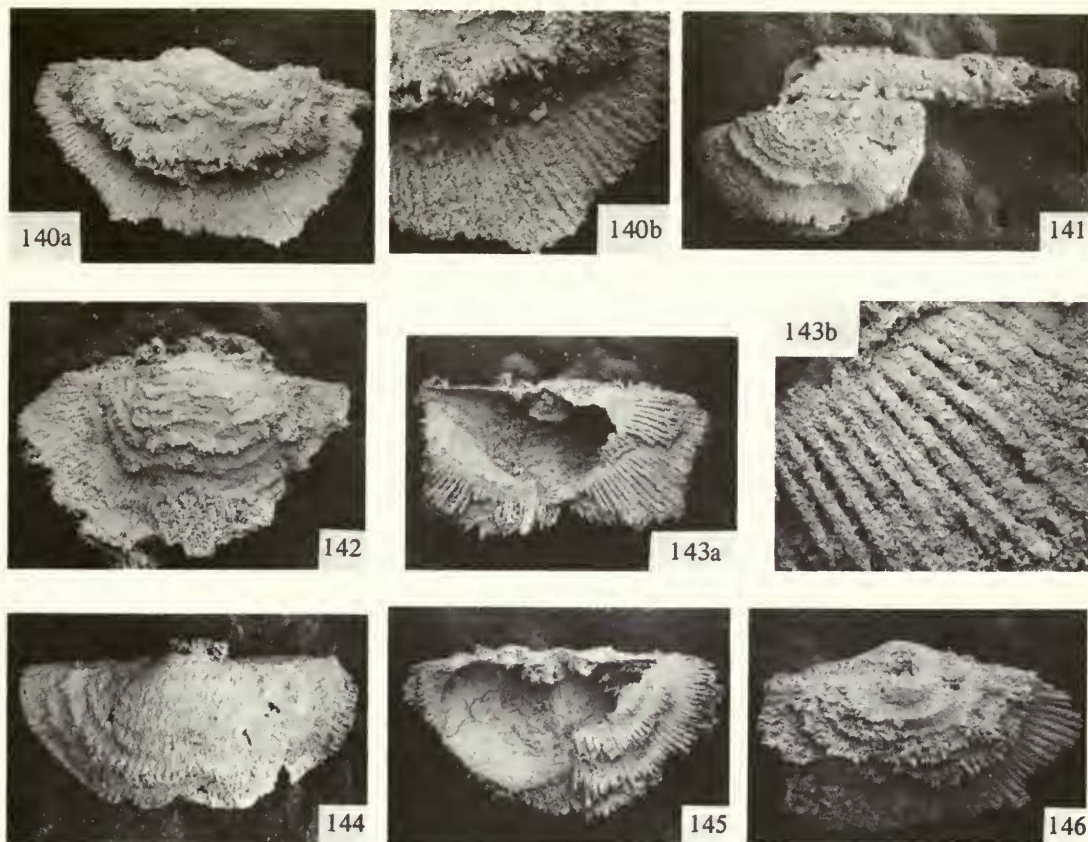
Ventral interior with small triangular teeth supported by short, receding, parallel, dental plates forming lateral margin of posteriorly-rounded free spondylium with dimensions of  $0.5 \times 0.5$  mm in one specimen.

Dorsal interior with prominent, erect brachiophores flanked by shallow, triangular, sockets defined by thin fulcral plates and supported by well-developed, inclined, coalescing, brachiophore bases.

HOLOTYPE. Conjoined valves; BB 95495a, b: length 1.5 mm, width 2.8 mm. Fig. 140.

		length	width (mm)
PARATYPES.	Conjoined valves; BB 95498a, b	1.3	2.2
	Conjoined valves; BB 95500a, b	1.0	2.1
	Conjoined valves; BB 95501a, b	1.3	2.1
	Conjoined valves; BB 95616a, b	1.5	2.6
	Pedicle valve; BB 95496	1.5	2.5
	Pedicle valve; BB 95499	1.4	2.8
	Brachial valve; BB 95497	1.7	2.9





**Figs 140–146** *Crossiskenidium?* *lamellosum* sp. nov. Fig. 140, holotype BB 95495, dorsal view of conjoined valves: a,  $\times 17$ ; b, enlargement of ornamentation,  $\times 35$ ; Fig. 141, paratype BB 95616, dorsal view of conjoined valves attached(?) to hollow tube,  $\times 12$ ; Fig. 142, paratype BB 95501, ventral view of conjoined valves,  $\times 16$ ; Fig. 143a, b, paratype BB 95496, interior of pedicle valve: a,  $\times 11$ ; b,  $\times 44$ ; Fig. 144, paratype BB 95499, exterior of pedicle valve,  $\times 14$ ; Fig. 145, paratype BB 95497, interior of brachial valve,  $\times 13$ ; Fig. 146, paratype BB 95500, dorsal view of conjoined valves,  $\times 20$ .

**TYPE HORIZON AND LOCALITY. Loc. 1.**

**DISCUSSION.** Apart from representatives of the type species of *Crossiskenidium*, the Tourmakeady residues also yielded a small sample of distinctively ornamented minute brachiopods, which on the available information may be provisionally assigned to the new genus. The sample consists predominantly of conjoined valves, along with a few separated valves which are mostly fragmentary and have much of their internal morphology obscured by siliceous encrustations. However, dissections of some conjoined valves revealed sufficient information on the form of the dorsal cardinalia and the ventral muscle field to demonstrate unequivocally their skenidiid affinities. Thus the presence of a free spondylium in the pedicle valve, and inclined brachiophore bases uniting with the valve floor in the dorsal valve, are diagnostic of this family. Externally, however, the specimens bear lamellae which are proportionately larger than those in *C. spinosum* and which do not bear rows of flat spines along their peripheries. Other features which further justify the erection of at least a new species are the finer radial ornamentation and the development, interiorly, of a free spondylium.

Genus *PROTOSKENIDIOIDES* Williams, 1974*Protoskenidioides hibernicus* sp. nov.

Figs 147–152

DIAGNOSIS. Transversely semi-oval mucronate *Protoskenidioides*, with a strongly convex pedicle valve averaging 49% as long as wide and 57% as deep as long, and a gently convex to almost planar brachial valve averaging 50% as long as wide and 59% as deep as long at sharply sulcate anteromedian margin; external ornamentation costate with an average of 14 rounded ribs in adult brachial valves.

NAME. 'Irish'.

DESCRIPTION. Small, transversely semi-oval mucronate *Protoskenidioides* with juvenile specimens flattened, sub-pyramidal; adult pedicle valves strongly convex averaging 49% as long as wide ( $\bar{l}$  mm (var l) 1.69 (0.094),  $\bar{w}$  mm (var w) 3.47 (0.238),  $r = 0.747$ ;  $n = 10$ ) and 57% as deep as long ( $\bar{l}$  mm (var l) 1.64 (0.150),  $\bar{th}$  mm (var th) 0.93 (0.047),  $r = 0.932$ ;  $n = 14$ ); brachial valve gently convex to almost planar, on average 50% as long as wide ( $\bar{l}$  mm (var l) 1.60 (0.037),  $\bar{w}$  mm (var w) 3.27 (0.160),  $r = 0.629$ ;  $n = 10$ ) and with a maximum thickness at sharply sulcate anteromedian margin averaging 59% of valve length ( $\bar{l}$  mm (var l) 1.48 (0.037),  $\bar{th}$  mm (var th) 0.87 (0.010),  $r = 0.802$ ;  $n = 9$ ); lateral margins of both valves smoothly rounded, anterior margins rounded or slightly truncated, commonly bilobed by sharp, narrow, dorsal median sulcus on average 0.48 mm wide (range 0.3–0.6 mm in 7 valves) at one mm anteromedially of dorsal umbo; radial ornamentation costate, with 12–16 ribs on 1, 4, 6, 2 and 1 brachial valves respectively; strong ventral median costa forms carina of pedicle valve complimentary to dorsal sulcus and attains a maximum width of 0.5 mm in 4 adult valves; ventral interarea broad, apsacline, gently curved, with open delthyrium, dorsal interarea narrow, planar, anacline.

Ventral interior with short, tapering teeth, and shallow, concave, free spondylium, rounded anteriorly, averaging 69% as wide as long ( $\bar{l}_{sp}$  mm (var  $l_{sp}$ ) 0.53 (0.007),  $\bar{w}_{sp}$  mm (var  $w_{sp}$ ) 0.37 (0.007),  $r = 0.8$ ;  $n = 6$ ) and extending for an average of 61% of the length of the ventral interarea ( $\bar{l}_{sp}$  mm (var  $l_{sp}$ ) 0.53 (0.013);  $\bar{l}_{in}$  mm (var  $l_{in}$ ) 0.87 (0.017),  $r = 0.573$ ;  $n = 9$ ).

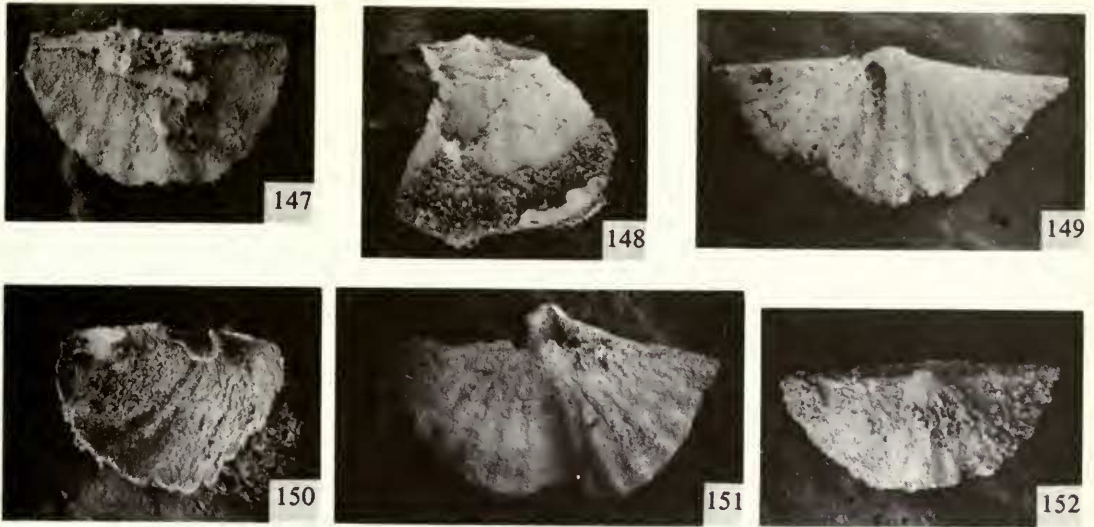
Dorsal interior with narrow, subparallel, erect brachiophores flanked by narrow triangular sockets constrained anterolaterally by well-defined fulcral plates, brachiophores extending ventrally up to 0.8 mm above valve floor, supported by strong, curved, brachiophore bases united medially in adult specimens to form elevated bilobed anterior margin of notothyrial platform averaging 88% as long as wide ( $\bar{l}_n$  mm (var  $l_n$ ) 0.48 (0.002),  $\bar{w}_n$  mm (var  $w_n$ ) 0.53 (0.003),  $r = 0.547$ ;  $n = 6$ ); faint low rounded cardinal process developed posteromedially on notothyrial platform; floor of brachial valve with long, low, rounded, median septum extending anteriorly for an average of 1.1 mm in 5 adult valves (range 1.1–1.2 mm), anterior margin of median septum abruptly elevated to form prominent erect spine extending up to 0.7 mm above valve floor in adult specimens; adductor muscle field divided by median septum into pair of elongately oval, subparallel, impressions defined anteriorly and laterally by elevated rim, and with dimensions of 0.5 × 0.3 mm in one specimen.

HOLOTYPE. Complete brachial valve; BB 95451: length 1.5 mm, width 2.6 mm. Fig. 147.

PARATYPES.		length	width (mm)
	Conjoined valves; BB 95452a, b	1.8	3.2
	Conjoined valves; BB 95454a, b	1.1	2.6
	Conjoined valves; BB 95456a, b	0.5	2.2
	Incomplete pedicle valve; BB 95453	1.3	–
	Incomplete brachial valve; BB 95455	–	–

TYPE HORIZON AND LOCALITY. Loc. 1.





**Figs 147–152** *Protoskenidioides hibernicus* sp. nov. Fig. 147, holotype BB 95451, interior of brachial valve,  $\times 14$ ; Fig. 148, paratype BB 95455, interior of incomplete brachial valve,  $\times 16$ ; Fig. 149, paratype BB 95454, ventral view of conjoined valves,  $\times 19$ ; Fig. 150, paratype BB 95453, interior of pedicle valve,  $\times 18$ ; Fig. 151, paratype BB 95452, dorsal view of conjoined valves,  $\times 14$ ; Fig. 152, paratype BB 95456, ventral view of juvenile conjoined valves,  $\times 22$ .

**DISCUSSION.** The genus *Protoskenidioides* was erected to incorporate primitive skenidiids characterized by a pattern of cardinalia development which had not previously been recorded in this family (Williams 1974: 83). In juvenile *Protoskenidioides* the brachiophore bases are discrete, but in adult valves subsequently unite medially to form a bilobed notothyrial platform surmounted posteriorly by a narrow ridge-like cardinal process marking the line of suture. Concomitantly the median septum, initially a discrete low narrow ridge situated anteriorly of the brachiophore bases, grows both anteriorly and posteriorly and unites with the anterior margin of the notothyrial platform (Williams 1974: 84). This contrasts with the pattern of cardinalia development in other skenidiids, such as *Skenidioides*, in which the notothyrial platform is evenly convex anteriorly in both juveniles and adults, and shows no signs of having developed from the coalescence of discrete brachiophore bases. The recognition of the *Protoskenidioides*-type of development in the Tourmakeady specimens confirms their assignment to that genus rather than to *Skenidioides*; externally the two genera are very similar in appearance.

The Tourmakeady specimens have many features in common with *P. revelata* (Williams 1974: 85), the type species of the genus from the Arenig of Shropshire. Apart from the similarity in cardinalia development mentioned above, the two stocks are virtually indistinguishable in shell size and proportions and in number of ribs. However, differences which justify the recognition of the Tourmakeady specimens as a new species are discernible, in particular the development of a spinose extension on the median septum and a curved ventral interarea. In addition the proportions of the notothyrial platform readily distinguish the two stocks, being strongly transverse in *P. revelata* (about half as long as wide) as compared with only slightly transverse in the Irish specimens (ranging from 80–100% as long as wide).



## Suborder CLITAMBONITIDINA Öpik, 1934

## Superfamily CLITAMBONITACEA Winchell &amp; Schuchert, 1893

## Family POLYTOECHIIDAE Öpik, 1934

Genus *ACANTHOTOECHIA* nov.

DIAGNOSIS. Medium-sized, concavo-convex polytoechiid, subelliptical to semicircular in outline; pedicle valve moderately to strongly convex with prominent, tapering, triangular umbo; brachial valve gently and smoothly concave; external ornamentation unequally parvicostellate, with ribs bearing rows of fine, hollow spines peripherally; ventral interarea broad, planar, apsacline, delthyrium closed dorsally by well-developed, smoothly rounded, strongly convex pseudodeltidium, posteriorly enclosing circular pedicle foramen, dorsal interarea narrow, catacline, notothyrium flanked by weak chilidial plates.

Ventral interior with small, thickened, triangular teeth supported by well-developed, divergent, dental plates defining lateral margins of tripartite ventral muscle field with prominent, elevated median adductor scar callist; ventral mantle canal system unknown.

Dorsal interior with narrow, thickened cardinalia with well-developed, gently curved, socket ridges defining narrow triangular sockets and supported by callus deposits laterally to define narrow notothyrial platform surmounted by thickened, ridge-like, cardinal process; floor of valve with well-defined subperipheral ridge; muscle attachment scars and mantle canal system unknown.

NAME. Greek, *ἀκανθώδης*, thorny, + *τοιχος*, wall.

TYPE SPECIES. *Acanthotoechia hibernica* sp. nov. from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. A small sample of shells from the Tourmakeady Limestone can confidently be assigned to the Polytoechiidae on the basis of a strong, arched pseudodeltidium and characteristic internal morphology. Their external ornamentation, however, parvicostellate with fine erect spines, has not previously been recorded in any polytoechiid and warrants generic recognition. The majority of polytoechiids are finely multicostellate; and in *Tritoechia* swollen hollow costellae are a conspicuous component of the radial ornamentation but these are never prolonged into spines.

In other respects the new genus appears closest to *Pomatotrema* Ulrich & Cooper, both being distinguished from other described unequally biconvex polytoechiids in their concavo-convex profile. Internally the ventral muscle field and cardinalia of the new genus are also similar to those in *Pomatotrema*. In *Pomatotrema*, however, the dental plates are much more strongly developed and do not recede as in the Irish specimens.

The only species, *Acanthotoechia hibernica*, is at present known only from the Tourmakeady Limestone.

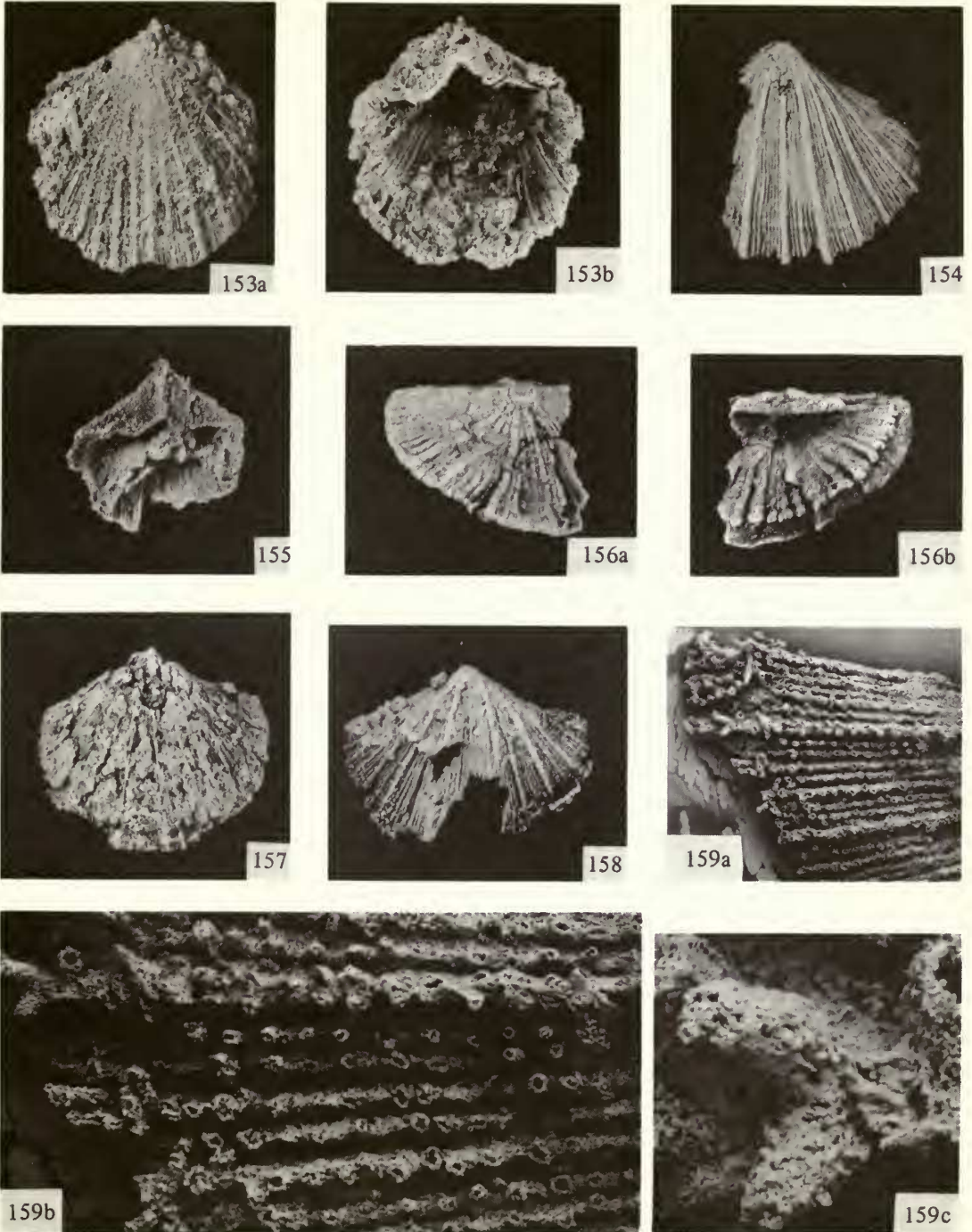
*Acanthotoechia hibernica* sp. nov.

Figs 153–159

DIAGNOSIS. Medium-sized, subelliptical to semicircular *Acanthotoechia*; pedicle valve averaging 100% as long as wide and 31% as deep as long; brachial valve subquadrate to semicircular averaging 66% as long as wide and 20% as deep as long; external ornamentation unequally parvicostellate with 6 or 7 rounded ribs per mm at 2 mm anteromedially of dorsal umbo, swollen primary ribs bearing two rows of fine cylindrical spines, erect in lateral view but inclined laterally when viewed anteriorly, and with an average diameter of 80 μm, fine intermediary ribs each bearing a single row of hollow erect spines with an average maximum diameter of 60 μm.

NAME. 'Irish'.

DESCRIPTION: Medium-sized, concavo-convex *Acanthotoechia*, subelliptical to semicircular in



**Figs 153–159** *Acanthoecchia hibernica* gen. et sp. nov. Fig. 153a, b, **holotype** BB 95510, exterior and interior of pedicle valve, both  $\times 4$ ; Fig. 154, paratype BB 95514, exterior of incomplete pedicle valve,  $\times 5$ ; Fig. 155, paratype BB 95516, interior of incomplete pedicle valve,  $\times 6$ ; Fig. 156a, b, paratype BB 95515, exterior and interior of juvenile brachial valve, both  $\times 8$ ; Fig. 157, paratype BB 95511, ventral view of conjoined valves,  $\times 4$ ; Fig. 158, paratype BB 95512, exterior of incomplete pedicle valve,  $\times 5$ ; Fig. 159a, b, c, paratype BB 95356, external spinose ornamentation on fragment: a,  $\times 17$ ; b,  $\times 50$ ; c, twin spines on primary rib,  $\times 200$ .



outline with prominent, tapering, triangular ventral umbo; pedicle valve moderately to strongly convex averaging 100% as long as wide (ranging from 98% as long as wide to 98% as wide as long in two specimens) and averaging 31% as deep as long (range 25–36%;  $n = 2$ ); brachial valve gently concave, transversely subquadrate to semicircular, averaging 66% as long as wide (range 65–67%;  $n = 2$ ) and with a maximum thickness averaging 20% of valve length (range 18–21%;  $n = 2$ ); lateral and anterior margins of both valves strongly and evenly rounded; external ornamentation unequally parvicostellate with 6 or 7 rounded ribs per mm at 2 mm anteromedially of the umbones of two brachial valves, divided into narrowly triangular sectors by a moderate to strong thickening of every fifth to seventh rib; external surfaces spinose with accentuated primary ribs bearing two rows of fine, cylindrical hollow spines, erect in lateral view but inclined laterally when viewed anteriorly and with an average maximum diameter of 80  $\mu\text{m}$  (range 70–90  $\mu\text{m}$ ;  $n = 12$ ), fine intermediary ribs each bearing a single row of fine, cylindrical, hollow, erect spines with an average maximum diameter of 60  $\mu\text{m}$  (range 50–65  $\mu\text{m}$ ;  $n = 14$ ); ventral interarea broad, triangular, planar, apsacline, delthyrium closed dorsally by well-developed, smoothly rounded, convex pseudodeltidium enclosing posteriorly-situated circular pedicle foramen with a maximum diameter of 0.6 mm in 3 specimens, dorsal interarea very narrow, catacline, notothyrium flanked by weakly-developed chilidial plates.

Ventral interior with small, thickened, triangular teeth supported by well-developed, receding, dental plates forming lateral margins of well-defined, broadly triangular, sessile, ventral muscle field averaging 91% as long as wide (range 87–94%;  $n = 2$ ), muscle field tripartite with prominent, narrowly triangular, elevated median adductor ridge with a maximum width anteriorly of 0.6 mm in two specimens.

Dorsal interior with narrow, thickened cardinalia with well-developed, gently curved, socket ridges defining narrowly triangular sockets supported by callus deposits laterally to define narrow notothyrial platform surmounted by thickened ridge-like cardinal process.

HOLOTYPE. Pedicle valve; BB 95510: length 9.1 mm, width 8.6 mm. Fig. 153.

PARATYPES.		length	width (mm)
Conjoined valves; BB 95511a, b		7.7	8.0
Incomplete pedicle valve; BB 95512		—	8.6
Incomplete pedicle valve; BB 95514		6.5	—
Incomplete pedicle valve; BB 95516		—	—
Incomplete pedicle valve; BB 95356		—	—
Brachial valve; BB 95513		5.1	7.6
Incomplete brachial valve; BB 95515		3.1	—

TYPE HORIZON AND LOCALITY. Loc. 1.

### Genus *POMATOTREMA* Ulrich & Cooper, 1932

#### *Pomatotrema inconspicuum* sp. nov.

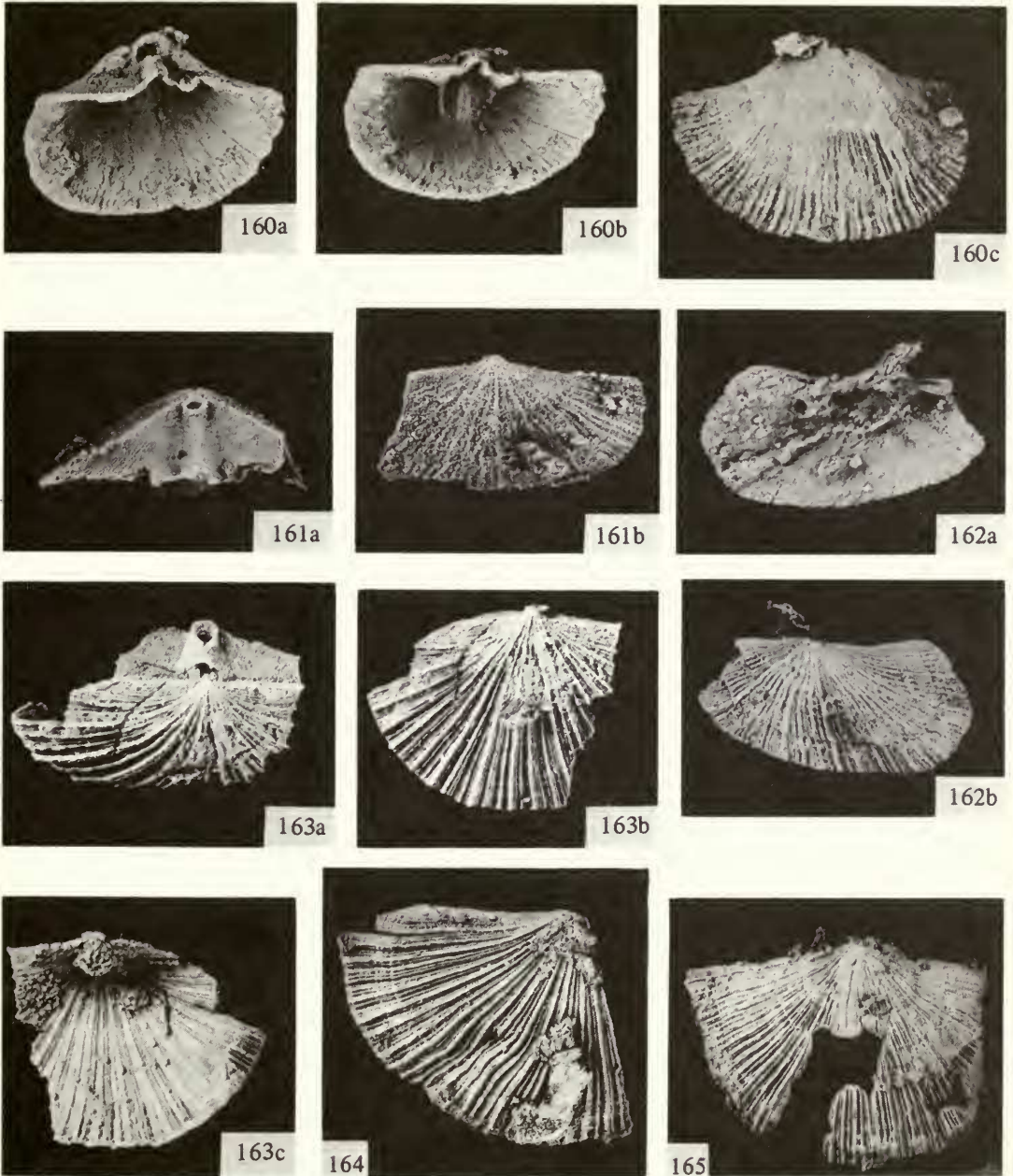
Figs 160–162

DIAGNOSIS. Small, biconvex to almost plano-convex *Pomatotrema*, strongly transversely ovate in outline; pedicle valve strongly convex averaging 56% as long as wide and 56% as deep as long with prominent tapering ventral umbo; brachial valve shallowly convex to almost planar, 43% as long as wide and 28% as deep as long; external ornamentation multicostellate with 6–7 ribs per mm at 2 mm anteromedially of dorsal umbo.

NAME. 'Unremarkable'.

DESCRIPTION. Small, biconvex to almost plano-convex *Pomatotrema*, strongly transversely ovate in outline with prominent tapering, triangular, ventral umbo; pedicle valve strongly convex averaging 56% as long as wide (range 52–66%;  $n = 4$ ) and 56% as deep as long (range 51–60%;  $n = 4$ ); brachial valve gently convex, especially posteromedially, becoming





**Figs 160–162** *Pomatotrema inconspicuum* sp. nov. Fig. 160a, b, c, holotype BB 95522, pedicle valve: a, interior,  $\times 4$ ; b, inclined anterior view of valve interior,  $\times 4$ ; c, exterior,  $\times 5$ ; Fig. 161a, b, paratype BB 95524, posterior and external views of incomplete pedicle valve: a,  $\times 4$ ; b,  $\times 5$ ; Fig. 162a, b, paratype BB 95525, interior and exterior of brachial valve, both  $\times 5$ .

**Figs 163–165** *Tritoechia* sp. Fig. 163a, b, c, BB 95529, posterior, dorsal and ventral views of incomplete conjoined valves: a,  $\times 4$ ; b, c, both  $\times 3$ ; Fig. 164, BB 95530, exterior of incomplete brachial valve,  $\times 2$ ; Fig. 165, BB 95528, exterior of incomplete brachial valve,  $\times 2$ .

almost planar anteriorly and anterolaterally, 43% as long as wide in one specimen and attaining a maximum thickness of 28% of valve length posteromedially; lateral margins of both valves strongly rounded, anterior margins gently rounded to almost planar; external ornamentation multicostellate with 6–7 rounded ribs per mm at 2 mm anteromedially of dorsal umbones of two brachial valves; ventral interarea broad, triangular, strongly to moderately apsacline, planar or slightly concave, delthyrium closed dorsally by well-developed, strongly arched pseudodeltidium enclosing posteriorly situated pedicle foramen with a maximum diameter of 0.7 mm in 4 specimens; dorsal interarea narrow, planar, catacline, notothyrium covered by gently arched chilidial plates.

Ventral interior with small, thickened, triangular teeth supported by strongly receding dental plates very faint dorsally but becoming prominent and thickened posteriorly to form lateral margins of well-defined, elongately oval, tripartite ventral muscle field with prominent, elongately oval, rounded, median adductor ridge flanked by narrow, parallel-sided, diductor scars.

Dorsal interior with narrow, thickened cardinalia with well-developed, thickened, rounded, gently curved, socket ridges defining narrow triangular sockets, and united medially to define small triangular notothyrial platform surmounted by thickened, rounded, ridge-like cardinal process; notothyrial platform supported medially to floor of valve by short, rounded, thickened, median ridge.

**HOLOTYPE.** Pedicle valve; BB 95522: length 5.9 mm, width 8.9 mm. Fig. 160.

**PARATYPES.** Pedicle valve, BB 95526 (length 3.8 mm, width 7.1 mm); incomplete pedicle valve, BB 95524; incomplete brachial valves BB 95523, 95525 (length 3.5 mm), 95527.

**TYPE HORIZON AND LOCALITY.** Loc. 1.

**DISCUSSION.** The combination of polytoechiid cardinalia, distinctive ventral morphology, almost planar brachial valve, and multicostellate ornamentation confirms the presence of representatives of *Pomatotrema* in the Tourmakeady Limestone.

When compared with other species of *Pomatotrema*, the Irish stock is noticeably more transversely oval, more so even than *P. transversum* Ulrich & Cooper (1938: 174) from the Lower Ordovician Arbuckle Limestone of Oklahoma. The Irish species is further distinguished by the presence of a relatively well-developed, catacline, dorsal umbo. In addition *P. inconspicuum* is smaller than most described species of *Pomatotrema*, but has a proportionately much larger pedicle foramen.

### Genus *TRITOECHIA* Ulrich & Cooper, 1936

#### *Tritoechia* sp.

Figs 163–165

**DIAGNOSIS.** Large, biconvex, transversely semi-elliptical *Tritoechia*; pedicle valve moderately curved with a prominent, gently rounded, umbo, about 67% as long as wide and 25% as deep as long; brachial valve moderately convex, about 45% as long as wide and 30% as deep as long; radial ornamentation fascicostellate with 5 or 6 angular ribs per mm at 5 mm anteromedially of dorsal umbo.

**DESCRIPTION.** Large, biconvex, transversely semi-elliptical *Tritoechia*; pedicle valve moderately convex, attaining an estimated maximum length of 20 mm and about 67% as long as wide and 25% as deep as long, brachial valve moderately convex with minute umbo, estimated to be 45% as long as wide and 30% as deep as long; radial ornamentation fascicostellate with 5 or 6 angular ribs per mm at 5 mm anteromedially of the dorsal umbones of two specimens, ribs hollow, especially in adult growth stages; ventral interarea broad, triangular, planar to slightly concave, moderately apsacline to almost catacline, delthyrium closed by strong arched pseudodeltidium enclosing posteriorly-situated circular pedicle

foramen with a diameter of 0.8 mm in one specimen, dorsal interarea very narrow, planar, anacline, notothyrium covered by small chilidial plates.

Ventral interior with small, triangular, thickened teeth supported by strongly receding dental plates forming lateral margins of tripartite ventral muscle field.

Dorsal interior with small thickened cardinalia consisting of socket ridges joined medially by callus deposits.

FIGURED MATERIAL. Incomplete conjoined valves, BB 95529a, b (length 8.4 mm); incomplete pedicle valve, BB 95528 (length 19.6 mm); incomplete brachial valve, BB 95530 (length 14.1 mm). All Loc. 1.

DISCUSSION. In addition to the new species of *Pomatotrema* Ulrich & Cooper and *Acanthotoechia* gen. nov., the Tourmakeady Limestone yielded a small number of incomplete specimens clearly belonging to a third polytoechiid genus. The specimens are distinguished from the other two genera by being much larger and more strongly biconvex, and by having a distinctive fascicostellate ornamentation of hollow, angular, ribs. These features suggest an affinity with *Tritoechia* Ulrich & Cooper. Certainly those aspects of internal morphology which can be determined in the sparse, partially preserved Irish specimens support this belief.

The size and external morphology of the Irish specimens are reminiscent of *T. occidentalis* Ulrich & Cooper (1938: 164) from the Lower Ordovician Sarbach Formation of Canada. However, the former can readily be distinguished by their fascicostellate ornamentation and considerably more transverse outline. In view of the lack of detailed information on internal morphology, no meaningful comparison between the Irish stock and its assumed congeneric species is possible, and specific recognition is withheld.

### Superfamily indet.

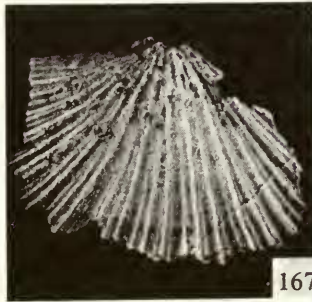
#### Orthidina gen. et sp. indet.

Figs 166–168

A small number of specimens from the Tourmakeady residues (BB 95588–92) cannot be identified generically because their internal morphology is indeterminable. The specimens are ventribiconvex, transversely subquadrate to semicircular in outline, and have a fascicostellate ornamentation. The delthyrium and notothyrium appear to be open, which suggests that the specimens are orthaceans.



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167



168

**Figs 166–168** Orthidina, gen. et sp. indet. Fig. 166, BB 95588, ventral view of conjoined valves,  $\times 4$ ; Fig. 167, BB 95590, exterior of pedicle valve,  $\times 4$ ; Fig. 168, BB 95589, exterior of brachial valve,  $\times 4$ .



Order STROPHOMENIDA Öpik, 1934  
 Suborder STROPHOMENIDINA Öpik, 1934  
 Superfamily PLECTAMBONITACEA Jones, 1928  
 Family PLECTAMBONITIDAE Jones, 1928  
 Subfamily AHTIELLINAE Öpik, 1933  
 Genus *BORUA* nov.

DIAGNOSIS. Medium-sized, moderately to strongly transversely semi-elliptical to semicircular plectambonitids, with strongly resupinate lateral and anterior margins, external surfaces smooth or with faint peripheral parvicostellate ornamentation crossed by faint impersistent concentric rugae; ventral interarea planar, strongly apsacline to orthocline, delthyrium closed posteriorly by gently arched pseudodeltidium, dorsal interarea narrow, planar, anacline, notothyrium covered by gently arched chilidium.

Ventral interior with small, triangular teeth supported by short, receding, subparallel dental plates, flanking semi-elliptical muscle platform defined by fine, elevated, rounded rim; floor of valve with two narrow, subparallel canals of *vascula myaria* possibly representing saccate ventral mantle canal system, elevated subperipheral rim well-developed on floor of valve at point of resupination.

Dorsal interior with short, thickened brachiophores flanked by small, deeply incised sockets defined by elevated fulcral plates, notothyrium narrowly triangular, surmounted by low, ridge-like cardinal process; floor of valve with prominent subparallel rim developed at point of resupination; dorsal mantle canal system unknown.

NAME. After Brian Boru (926–1014), ancient High King of Ireland.

TYPE SPECIES. *Borua modesta* sp. nov., from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The Irish specimens possess all the characteristics of the Ahtielinae, but can readily be distinguished from all previously described genera in the subfamily. *Ahtiella* Öpik differs in possessing a well-developed radial ornamentation, a dorsal sulcus, and, internally, a prominent median septum in the brachial valve. *Inversella* Öpik, and *Ukoa* Öpik, on the other hand, are immediately distinguished by their external ornamentation – the former having strongly developed rugae and the latter having a distinctive parvicostellate ornamentation and pedicle foramen. Both *Gutasella* Neuman and *Reinversella* Bates differ from the Irish specimens in being doubly geniculate peripherally. In addition *Gutasella* lacks elevated subperipheral platforms internally. *Schedophyla* Neuman is also distinguished by its strong parvicostellate ornamentation, and a convex brachial valve. Only the brachial valve of *Rutrumella* Harper is known, but close affinity with the new Irish genus is ruled out by the presence, in the former, of a prominent dorsal median septum.

The new genus is at present monospecific, and known only from the Tourmakeady Limestone.

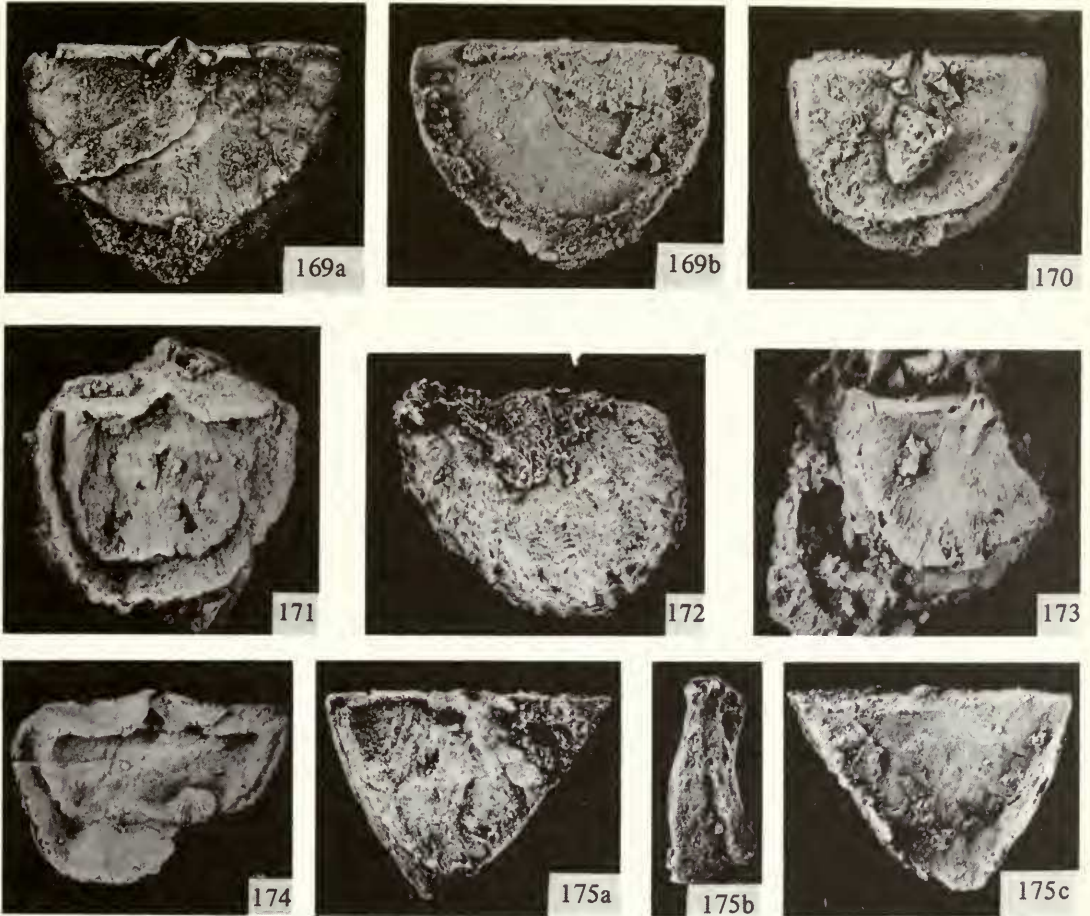
*Borua modesta* sp. nov.

Figs 169–175

DIAGNOSIS. Medium-sized, plano-convex, moderately to strongly semi-elliptical to semicircular *Borua*; pedicle valve gently convex, on average 77% as long as wide and 25% as deep as long; brachial valve planar with strong peripheral resupination, on average 70% as long as wide and 22% as deep as long; ventral muscle platform semi-elliptical, on average 79% as long as wide.

NAME. 'Moderate'.

DESCRIPTION. Medium-sized, moderately to strongly transversely semi-elliptical to semicircular *Borua*, plano-convex in profile with strongly resupinate lateral and anterior margins;



**Figs 169–175** *Borua modesta* gen. et sp. nov. Fig. 169a, b, holotype BB95531, interior and exterior of brachial valve, both  $\times 3$ ; Fig. 170, paratype BB95535, interior of brachial valve,  $\times 3$ ; Fig. 171, paratype BB95532, interior of pedicle valve,  $\times 3$ ; Fig. 172, paratype BB95534, exterior of pedicle valve,  $\times 3$ ; Fig. 173, paratype BB95533, interior of incomplete brachial valve,  $\times 3$ ; Fig. 174, paratype BB95536, interior of incomplete pedicle valve,  $\times 3$ ; Fig. 175a, b, c, paratype BB95537, internal, lateral and exterior views of incomplete brachial valve, all  $\times 4$ .

pedicle valve gently convex, ranging from strongly transversely semi-elliptical to slightly elongately semicircular, on average 77% as long as wide (ranging from 51% as long as wide to 97% as wide as long in 4 specimens) and 25% as deep as long (range 21–31%;  $n = 3$ ); brachial valve planar, with strong peripheral resupination, on average 70% as long as wide ( $\bar{l}$  mm (var l) 8.33 (0.709),  $\bar{w}$  mm (var w) 11.89 (0.148),  $r = 0.526$ ;  $n = 7$ ) and with a maximum thickness at resupinate anteromedian margin averaging 22% of valve length ( $\bar{l}$  mm (var l) 8.33 (0.709),  $\bar{h}$  mm (var th) 1.84 (0.053),  $r = 0.458$ ;  $n = 7$ ); external ornamentation smooth or with faint unequally parvicostellate ornamentation developed peripherally on trail, crossed by rare, impermanent, concentric rugae; ventral interarea planar, strongly apsacline to orthocline, extending anteriorly on average for 18% of valve length (range 14–20%;  $n = 3$ ), triangular delthyrium closed posteriorly by gently arched pseudodeltidium; dorsal interarea narrow, planar, anacline notothyrium covered by gently arched chilidium.

Ventral interior with small, thickened teeth supported by short, receding, thickened,



subparallel, dental plates, flanking poorly-defined transversely semi-elliptical ventral muscle platform on average 79% as long as wide (range 75–82%;  $n = 3$ ); ventral mantle canal system possibly saccate, with two subparallel canals of *vascula myaria* measuring 0.3 mm wide in one specimen.

Dorsal interior with short, thickened, tapering brachiophores extending anteriorly for an average of 13% of valve length ( $\bar{l}$  mm (var  $l$ ) 8.33 (0.709),  $\bar{l}_b$  (var  $l_b$ ) 1.10 (0.007),  $r = 0.685$ ;  $n = 7$ ) flanked by small, deeply-incised, sockets extending laterally for an average of 25% of valve width ( $\bar{w}$  mm (var  $w$ ) 11.89 (0.148),  $\bar{w}_{so}$  mm (var  $w_{so}$ ) 2.94 (0.050),  $r = 0.844$ ;  $n = 7$ ); notothyrial platform narrowly triangular on average 99% as long as wide ( $\bar{l}_n$  mm (var  $l_n$ ) 0.87 (0.280),  $\bar{w}_n$  mm (var  $w_n$ ) 0.87 (0.022),  $r = 0.954$ ;  $n = 9$ ) with narrow, ridge-like, rounded, median cardinal process; notothyrial platform buttressed medially by variably-developed, very short, median ridge.

HOLOTYPE. Brachial valve; BB 95531: length 9.1 mm, width 12.1 mm. Fig. 169.

		length	width (mm)
PARATYPES.	Pedicle valve; BB 95532	9.9	10.2
	Pedicle valve; BB 95534	9.4	11.4
	Pedicle valve; BB 95536	7.8	12.3
	Brachial valve; BB 95535	8.8	11.6
	Incomplete brachial valve; BB 95533	8.2	—
	Incomplete brachial valve; BB 95537	7.2	—

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. Statistical analysis of the main shape parameters of this species demonstrates its high degree of morphological variability, particularly in shell outline. However, ornamentation and internal morphology are standard throughout, confirming the taxonomic homogeneity of the sample.

Family **LEPTELLINIDAE** Ulrich & Cooper, 1936

Subfamily **LEPTELLININAE** Ulrich & Cooper, 1936

Genus **TOURMAKEADIA** nov.

DIAGNOSIS. Medium-sized, transversely semi-elliptical, concavo-convex leptellinids; pedicle valve moderately convex, brachial valve shallowly to moderately concave; external ornamentation costellate to parvicostellate; ventral interarea gently concave, apsacline, with broad, triangular, open delthyrium, dorsal interarea narrow, anacline, notothyrium open.

Ventral interior with small triangular teeth supported by short, strongly receding, divergent, dental plates flanking undifferentiated, sessile, transversely semicircular ventral muscle platform; floor of pedicle valve with prominent, radially striated, anteriorly bilobed, subperipheral platform defined peripherally by elevated striated ridge, ventral mantle canal system unknown.

Dorsal interior with slender, tapering, anteriorly diverging brachiophores flanked by shallow sockets; brachiophores supported laterally by inclined brachiophore bases sloping gently inwards to define broadly triangular, anteriorly bilobed, slightly concave, notothyrial platform surmounted medially by low, gently rounded, ridge-like, cardinal process; floor of valve with prominent, radially striated, anteriorly bilobed, subperipheral platform defined peripherally by elevated striated ridge; dorsal mantle canal system unknown.

NAME. From the locality of Tourmakeady.

TYPE SPECIES. *Tourmakeadia fimbriata* sp. nov., from the Tourmakeady Limestone, Co. Mayo.

DISCUSSION. The concavo-convex profile, prominent subperipheral platforms in both valves, and characteristic dorsal cardinalia confirm that the taxonomic affinities of the new stock lies



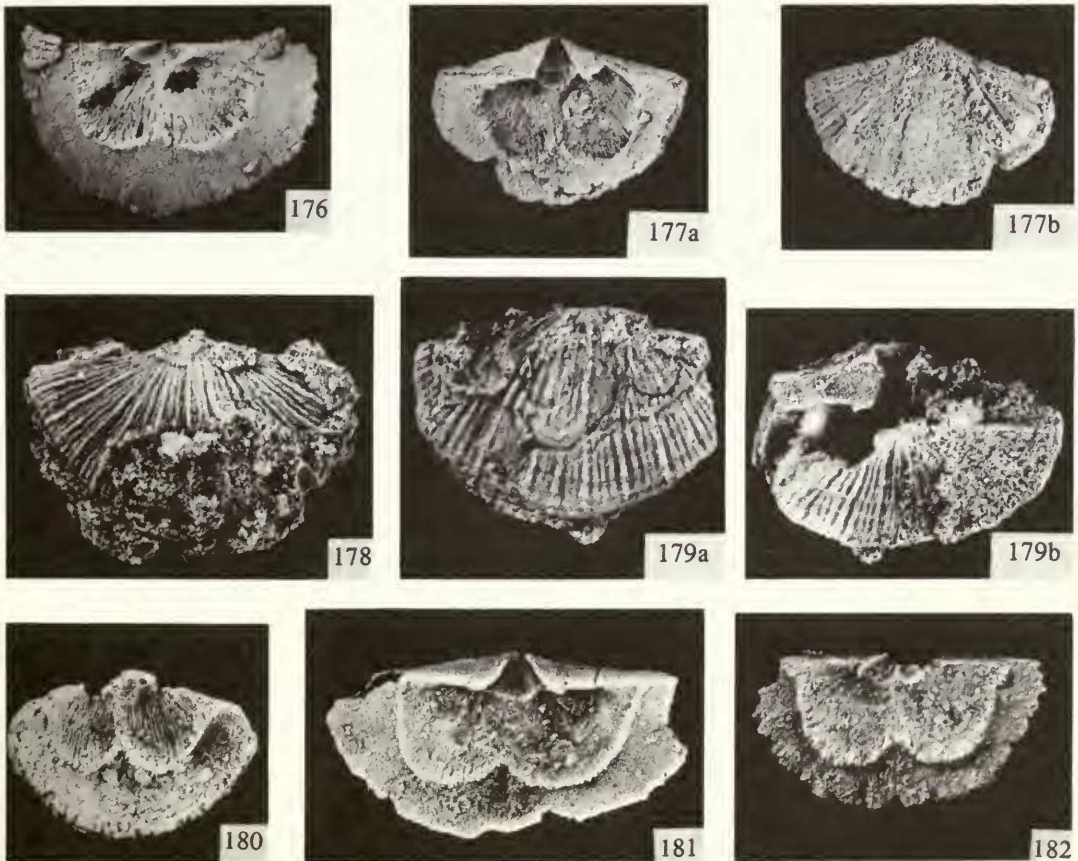
with the Leptellinae. Within the subfamily, *Tourmakeadia* most closely resembles *Anap-tambonites* Williams in external form, although the latter genus has a much finer ornamentation. Internally, however, the differences between the two stocks are much more apparent in that *Anap-tambonites* lacks a subperipheral platform in the ventral valve, and has a prominent dorsal median septum and a massive, differentiated, cardinal process. Although *Calytolepta* Neuman has internal subperipheral platforms in both valves, it is readily distinguished from the new genus by having a pronounced parvicostellate external ornamentation, a chilidium, an apically perforate pseudodeltidium, and internally a dorsal median septum.

*Tourmakeadia* is at present known only from the new species found in the Tourmakeady Limestone.

*Tourmakeadia fimbriata* sp. nov.

Figs 176–182

DIAGNOSIS. Medium-sized, transversely semi-elliptical, concavo-convex *Tourmakeadia*; ped-



**Figs 176–182** *Tourmakeadia fimbriata* gen. et sp. nov. Fig. 176, holotype BB 95538, interior of brachial valve,  $\times 5$ ; Fig. 177a, b, paratype BB 95539, interior and exterior of incomplete pedicle valve, both  $\times 4$ ; Fig. 178, paratype BB 95543, ventral view of conjoined valves,  $\times 4$ ; Fig. 179a, b, paratype BB 95541, ventral and oblique posterior views of conjoined valves, both  $\times 5$ ; Fig. 180, paratype BB 95544, interior of incomplete pedicle valve,  $\times 5$ ; Fig. 181, paratype BB 95542, interior of incomplete pedicle valve,  $\times 4$ ; Fig. 182, paratype BB 95540, interior of incomplete brachial valve,  $\times 6$ .

icle valve moderately convex averaging 59% as long as wide and 37% as deep as long; brachial valve shallowly to moderately concave, averaging 49% as long as wide and 25% as deep as long; external ornamentation costellate or slightly parvicostellate, with 4 to 5 rounded ribs per mm at 2 mm anteromedially of dorsal umbo.

NAME. 'Hemmed'.

DESCRIPTION. Medium-sized, transversely semi-elliptical, concavo-convex *Tourmakeadia*; pedicle valve moderately convex averaging 59% as long as wide (range 55–62%;  $n = 4$ ) and 37% as deep as long (range 36–38%;  $n = 3$ ); brachial valve shallowly to moderately concave, averaging 49% as long as wide ( $\bar{l}$  mm (var  $l$ ) 4.40 (0.282),  $\bar{w}$  mm (var  $w$ ) 8.94 (1.199),  $r = 0.957$ ;  $n = 12$ ) and 25% as deep as long ( $\bar{l}$  mm (var  $l$ ) 4.24 (0.300),  $\bar{th}$  mm (var  $th$ ) 1.06 (0.020),  $r = 0.762$ ;  $n = 8$ ); lateral and anterior margins of both valves smoothly rounded; external ornamentation costellate to slightly parvicostellate with 4 or 5 rounded ribs per mm at 2 mm anteromedially of umbones of 5 and 4 brachial valves respectively; triangular ventral interarea gently concave, apsacline, with broad, triangular, open delthyrium, dorsal interarea narrow, anacline, notothyrium open.

Ventral interior with small triangular teeth supported by short, strongly receding, divergent dental plates flanking undifferentiated, moderately to strongly transversely semicircular, sessile, ventral muscle platform with elevated anterior and anterolateral margins averaging 78% as long as wide (range 68–88%;  $n = 2$ ); floor of pedicle valve with prominent, radially striated, subperipheral platform defined by elevated, striated, ridge strongly bilobed anteromedially and averaging 53% as long as wide (range 46–60%;  $n = 2$ ).

Dorsal interior with slender, tapering, anteriorly divergent brachiophores, extending anteriorly on average for 20% of valve length ( $\bar{l}$  mm (var  $l$ ) 4.44 (0.396),  $\bar{l}_b$  mm (var  $l_b$ ) 0.89 (0.008),  $r = 0.660$ ;  $n = 7$ ), brachiophores flanked by shallow sockets extending laterally on average for 28% of valve width ( $\bar{w}$  mm (var  $w$ ) 8.93 (1.694),  $\bar{w}_{so}$  mm (var  $w_{so}$ ) 2.50 (0.083),  $r = 0.763$ ;  $n = 8$ ) and supported by gently inclined brachiophore bases defining broadly triangular, anteriorly bilobed, notothyrial platform extending anteriorly for an average for 19% of valve length ( $\bar{l}$  mm (var  $l$ ) 4.35 (0.403),  $\bar{l}_n$  mm (var  $l_n$ ) 0.87 (0.007),  $r = 0.926$ ;  $n = 6$ ), and averaging 64% as long as wide ( $\bar{l}_n$  mm (var  $l_n$ ) 0.87 (0.007),  $\bar{w}_n$  (var  $w_n$ ) 1.37 (0.019),  $r = 0.956$ ;  $n = 6$ ); floor of valve with prominent, radially striated, subperipheral platform, strongly bilobed anteromedially, defined by elevated striated ridge extending anteriorly for an average of 56% of valve length (range 52–60%;  $n = 5$ ) and averaging 45% as long as wide (range 43–48%;  $n = 5$ ).

HOLOTYPE. Brachial valve; BB 95538: length 4.5 mm, width 7.5 mm. Fig. 176.

PARATYPES.		length	width (mm)
Conjoined valves; BB 95543a, b		6.1	11.0
Incomplete conjoined valves; BB 95541a, b		5.5	—
Incomplete conjoined valves; BB 95545a, b		—	—
Incomplete pedicle valve; BB 95539		—	—
Incomplete pedicle valve; BB 95542		—	—
Incomplete pedicle valve; BB 95544		—	—
Brachial valve; BB 95540		3.6	7.2

TYPE HORIZON AND LOCALITY. Loc. 1.

Subfamily LEPTELLINAE Williams, 1965

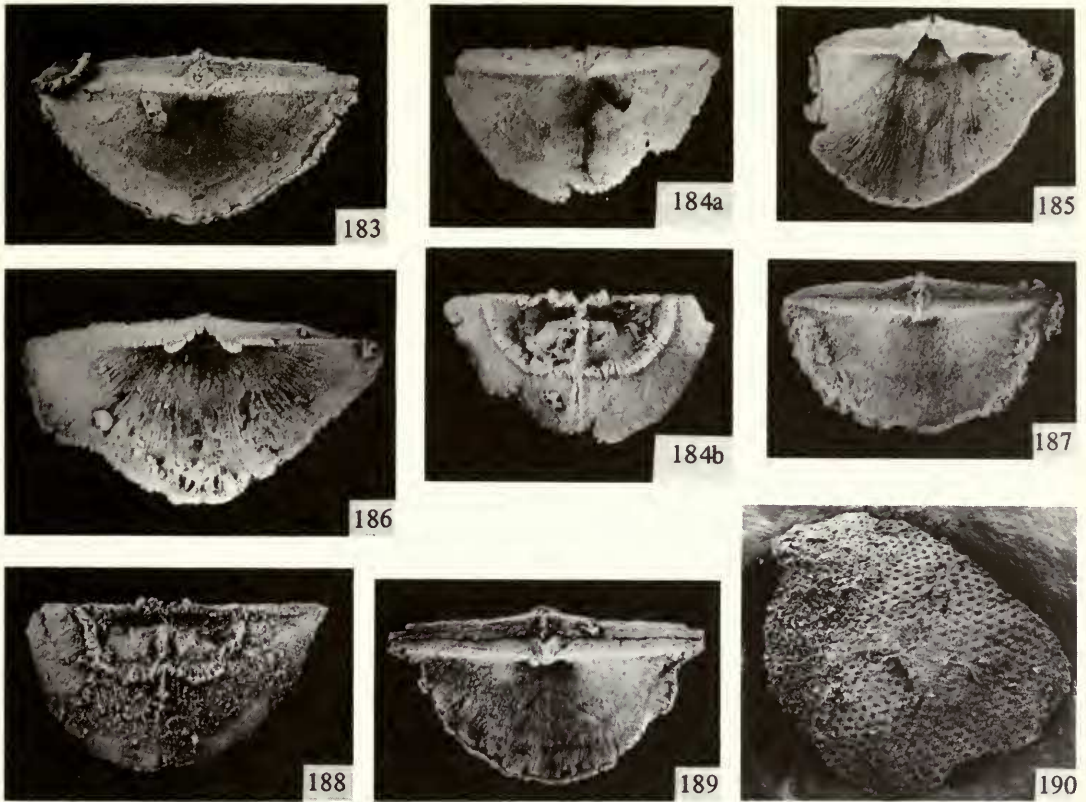
Genus *LEPTELLA* Hall & Clarke, 1892

*Leptella musculosa* sp. nov.

Figs 183–189

DIAGNOSIS. Medium-sized, moderately to strongly semi-elliptical or subquadrate *Leptella*,





**Figs 183–189** *Leptella musculososa* sp. nov. Fig. 183, **holotype** BB 95546, dorsal view of conjoined valves,  $\times 5$ ; Fig. 184a, b, paratype BB 95549, exterior and interior of brachial valve, both  $\times 5$ ; Fig. 185, paratype BB 95550, interior of incomplete pedicle valve,  $\times 4$ ; Fig. 186, paratype BB 95548, interior of pedicle valve,  $\times 5$ ; Fig. 187, paratype BB 95552, dorsal view of conjoined valves,  $\times 5$ ; Fig. 188, paratype BB 95547, interior of brachial valve,  $\times 5$ ; Fig. 189, paratype BB 95600, dorsal view of conjoined valves,  $\times 6$ .  
**Fig. 190** *Punctolira?* sp. BB 95601, fragment,  $\times 15$ .

pedicle valve moderately convex, averaging 63% as long as wide and 36% as deep as long, brachial valve moderately concave averaging 58% as long as wide and 41% as deep as long.

NAME. 'Musclcd'.

**DESCRIPTION.** Medium-sized, moderately to strongly semi-elliptical or subquadrate *Leptella*, pedicle valve moderately convex, averaging 63% as long as wide ( $\bar{l}$  mm (var l) 4.36 (1.394),  $\bar{w}$  mm (var w) 6.93 (2.305),  $r = 0.897$ ;  $n = 59$ ) and 36% as deep as long ( $\bar{l}$  mm (var l) 4.36 (1.394),  $\bar{t}h$  mm (var th) 1.58 (0.376),  $r = 0.920$ ;  $n = .59$ ), brachial valve moderately concave averaging 58% as long as wide ( $\bar{l}$  mm (var l) 4.28 (1.027),  $\bar{w}$  mm (var w) 7.38 (2.382),  $r = 0.887$ ;  $n = 52$ ) and 41% as deep as long ( $\bar{l}$  mm (var l) 4.28 (1.027),  $\bar{t}h$  mm (var th) 1.76 (1.028),  $r = 0.859$ ;  $n = 47$ ); lateral and anterior margins of both valves smoothly rounded, anterior margin with broad, gently curved sulcus in pedicle valve; external shell surfaces smooth, rarely with fine, faint, unequal parvicostellae; ventral interarea broad, triangular,



curved, orthocline, delthyrium sealed by moderately arched triangular pseudodeltidium, dorsal interarea broad, triangular, planar, strongly hypercline.

Ventral interior with short, thickened, triangular teeth supported by short, poorly-developed, subparallel, receding dental plates forming lateral margins of moderately well-defined, broadly triangular, ventral muscle field averaging 88% as long as wide ( $\bar{l}_{sc}$  mm (var  $l_{sc}$ ) 1.22 (0.014),  $\bar{w}_{sc}$  (var  $w_{sc}$ ) 1.38 (0.006),  $r = 0.720$ ;  $n = 18$ ) defined by low, rounded, elevated ridge of shell anteriorly and composed of large, median, triangular adductor scar extending anteriorly of small, narrowly triangular, flanking diductor scars, floor of valve occasionally with faint radial striae numbering up to 10 per mm at 5 mm anteromedially of umbo.

Dorsal interior with flattened, spatulate, erect brachiophores flanked by narrow, triangular sockets extending laterally on average for 22% of valve width ( $\bar{w}$  mm (var  $w$ ) 7.59 (1.987),  $\bar{w}_{so}$  mm (var  $w_{so}$ ) 1.68 (0.947),  $r = 0.834$ ;  $n = 34$ ), brachiophores supported by thickened, rounded, brachiophore bases continuous with well-developed chilidial plates defining small, triangular, shallowly concave, notothyrial platform averaging 69% as wide as long ( $\bar{l}_n$  mm (var  $l_n$ ) 0.63 (0.008),  $\bar{w}_n$  mm (var  $w_n$ ) 0.43 (0.007),  $r = 0.872$ ;  $n = 29$ ) covered posteriorly by gently arched, narrowly triangular chilidium; floor of brachial valve with well-developed, broadly semi-elliptical lophophore platform strongly elevated peripherally and averaging 42% as long as wide ( $\bar{l}_p$  mm (var  $l_p$ ) 2.08 (1.321),  $\bar{w}_p$  mm (var  $w_p$ ) 4.93 (2.143),  $r = 0.893$ ;  $n = 39$ ), lophophore platform bilobed anteriorly at narrow, low, subtriangular median septum arising on floor of valve anteriorly of notothyrial platform and extending almost to anterior margin of valve; floor of valve with pair of elongately crescentic adductor muscle scars impressed symmetrically on either side of median septum posteriorly of elevated rim of lophophore platform and averaging 53% as wide as long ( $\bar{l}_{sc}$  mm (var  $l_{sc}$ ) 1.28 (0.183),  $\bar{w}_{sc}$  mm (var  $w_{sc}$ ) 0.68 (0.037),  $r = 0.898$ ;  $n = 15$ ), floor of valve occasionally with fine radial striae numbering up to 10 per mm at 5 mm anteromedially of umbo.

HOLOTYPE. Conjoined valves; BB 95546a, b: length 4.9 mm, width 9.1 mm. Fig. 183.

		length	width (mm)
PARATYPES.	Conjoined valves; BB 95552a, b	3.9	6.8
	Conjoined valves; BB 95600a, b	4.4	7.9
	Pedicle valve; BB 95548	5.2	9.3
	Incomplete pedicle valve; BB 95550	—	—
	Brachial valve; BB 95549	4.6	7.9
	Incomplete brachial valve; BB 95547	—	7.8
	Incomplete brachial valve; BB 95551	—	—

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. The lack of a cardinal process internally and of a consistent radial ornamentation externally, combined with a strongly concavo-convex profile and characteristic dorsal cardinalia and lophophore platform, confirm that the Tourmakeady specimens are representatives of *Leptella*. Internally the Irish specimens are similar to the closely-related leptellin genus *Petroria* Wilson, although the latter genus lacks dental plates. Externally the two genera are readily distinguishable as *Petroria* has a prominent wavy, lamellose ornamentation (Cooper 1956: 747).

In size and shape the Irish specimens are similar to *Leptella sordida* (Billings), the type species of the genus, from the Lower Ordovician Levis Shales of Quebec (Ulrich & Cooper 1938: 189). However, the status of the Irish material as a new species is confirmed by the fact that *L. sordida* has a broader median septum, and much stronger and thicker brachiophores. In addition the well-developed dorsal adductor scars of *L. musculosa* are not evident in illustrations of *L. sordida*, nor are they mentioned in the accompanying description (Ulrich & Cooper 1938: 189). A further distinguishing feature is the unequally parvicostellate ornamentation of *L. sordida*, which, although faint, is better developed than on any Irish specimen.

Suborder **SYNTROPHIDINA** Ulrich & Cooper, 1936

Superfamily **PORAMBONITACEA** Davidson, 1853

Family **TETRALOBULIDAE** Ulrich & Cooper, 1936

Genus **PUNCTOLIRA** Ulrich & Cooper, 1936

*Punctolira?* sp.

Fig. 190

The Tourmakeady residues yielded a single incomplete specimen (BB 95601) with a distinctive, pitted, external ornamentation, similar to that which characterizes *Punctolira*, a small tetralobulid genus from Lower Ordovician successions in North America. Internally the only morphological details discernible in the Tourmakeady fragment are the incomplete remnants of a pair of well-developed lateral septa. With such inadequate criteria, generic identification cannot be made with certainty.

Family **CLARKELLIDAE** Schuchert & Cooper, 1931

Genus **ACANTHOGLYPHA** nov.

**DIAGNOSIS.** Medium-sized, transversely subquadrate clarkellid, pedicle valve moderately to strongly convex, brachial valve moderately convex with variably-developed anterior plication; external shell surface with closely spaced concentric ornamentation bearing dense concentric and radial arrays of hollow, erect to prone, spines each branching dichotomously anteriorly; ventral interarea triangular, strongly curved, anacline, delthyrium open, dorsal interarea narrow, slightly curved, anacline with open delthyrium.

Ventral interior with small, flattened, teeth supported by receding, convergent, dental plates forming lateral margins of elevated, tongue-shaped, spondylium supported by strong, thickened, median ridge; floor of valve with two pairs of narrow canals of digitate mantle canal system.

Dorsal interior with short, curved, thickened, triangular brachiophores supported by short, divergent bases sloping sharply down to valve floor to form lateral margins of broadly triangular, sessile, notothyrial platform; floor of valve with two discrete pairs of strongly elevated, elongately oval, adductor muscle scars; and three pairs of narrow, radiating branches of digitate mantle canal system.

**NAME.** Greek, ἀκανθώδης, thorny + γλύφη, carving.

**TYPE SPECIES.** *Acanthoglypha affinis* (Reed), from the Tourmakeady Limestone and associated sediments, Co. Mayo.

**DISCUSSION.** The distinctive association of a spondylium in the pedicle valve with small divergent brachiophore bases in the brachial valve confirms that the new genus is a representative of the Clarkellidae. Indeed the internal morphology of the pedicle valve of *Acanthoglypha* is virtually identical to that of other clarkellid genera such as *Thaumotrophia* Wang or *Stichotrophia* Cooper. However, the presence of dorsal muscle bases and, in particular, the nature of the external ornamentation, immediately distinguish *Acanthoglypha* from other clarkellid genera. The new Irish genus is closest to *Calliglypha* Cloud; internally the two stocks are similar, although the latter lacks prominent elevated dorsal muscle bases. Apart from this feature the chief differentiation between the two genera is the nature of the external ornamentation – dense spines in *Acanthoglypha* as compared with the radial and concentric nodes characteristic of *Calliglypha* (Cloud 1948). Dr G. A. Cooper kindly examined the type specimens of *Calliglypha* in the United States National Museum, Washington D.C., on our behalf and has confirmed that there is no suggestion of spines (Cooper, personal communication 1982). In addition, every specimen of *Acanthoglypha* from the Tourmakeady Limestone was closely examined to determine the proportion on



which, as a result of silicification or poor preservation, spines were not discernible. Out of a total sample of 164 specimens or fragments, no fewer than 142 (= 86.6%) had clear evidence of external spines. It is thus unlikely that the absence of spines on *Calliglypha* is a result of imperfect preservation, and hence the distinction between the two genera is substantiated.

*Acanthoglypha affinis* (Reed)

Figs 191–198

1909 *Streptis affinis* Reed in Gardiner & Reynolds: 151; pl. 6, figs 14a, b.

1978 *Calliglypha affinis* (Reed) Cocks: 136.

**DIAGNOSIS.** Medium-sized, subquadrate *Acanthoglypha*; pedicle valve moderately to strongly convex, averaging 64% as long as wide and 60% as deep as long; brachial valve moderately convex, averaging 47% as long as wide and 47% as deep as long; external surfaces with dense radial and concentric arrays of fine and coarse bifurcating hollow spines with maximum diameters of 50  $\mu$ m and 200  $\mu$ m, respectively.

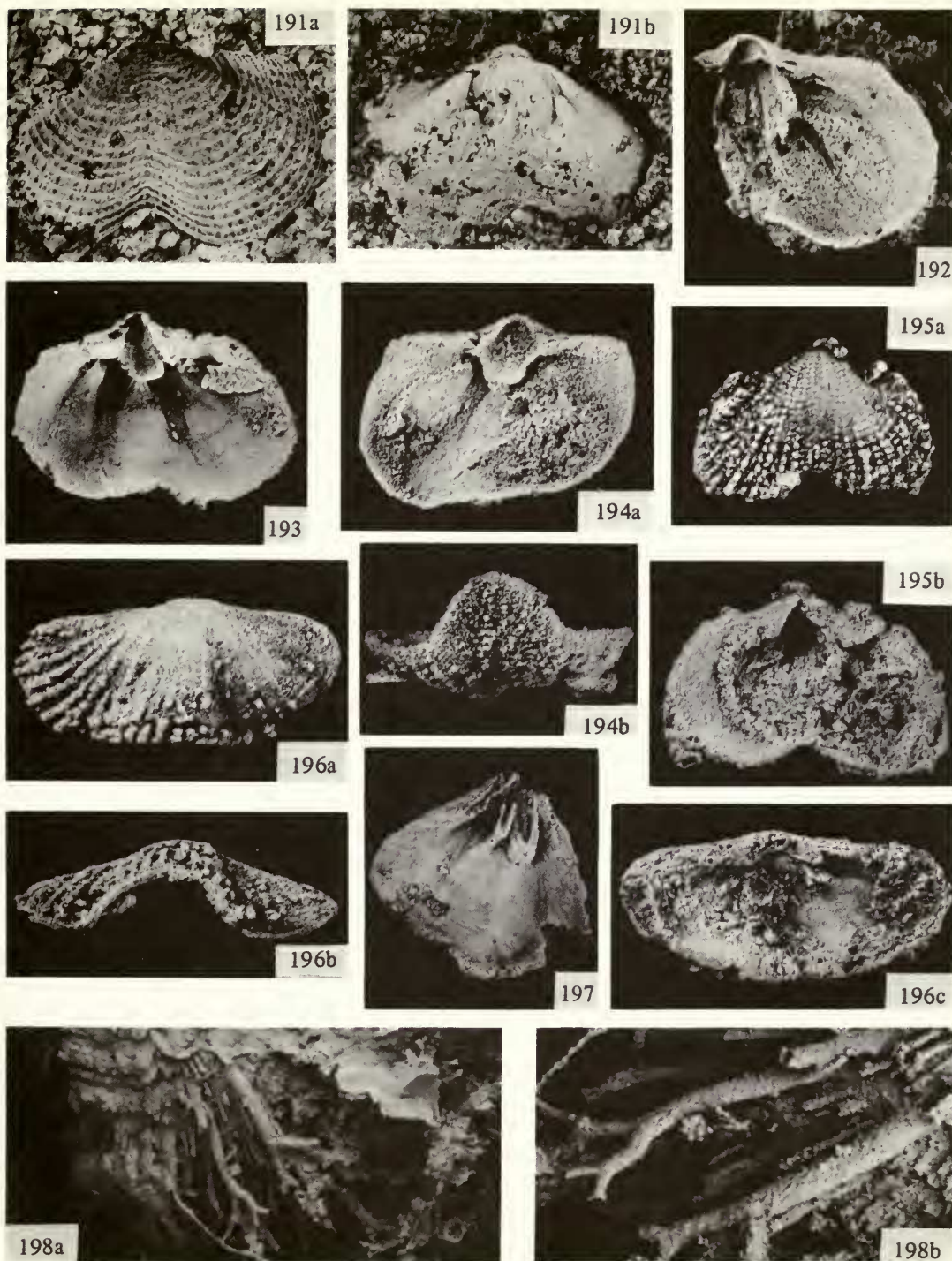
**DESCRIPTION.** Medium-sized, transversely subquadrate *Acanthoglypha*; pedicle valve moderately to strongly convex, averaging 64% as long as wide ( $\bar{l}$  mm (var l) 6.24 (1.216),  $\bar{w}$  mm (var w) 9.79 (2.211),  $r = 0.952$ ;  $n = 7$ ) and 60% as deep as long ( $\bar{l}$  mm (var l) 6.12 (1.326),  $\bar{th}$  mm (var th) 3.70 (0.544),  $r = 0.982$ ;  $n = 6$ ); brachial valve moderately convex averaging 47% as long as wide ( $\bar{l}$  mm (var l) 5.35 (1.086),  $\bar{w}$  mm (var w) 11.46 (6.706),  $r = 0.990$ ;  $n = 8$ ), and 47% as deep as long ( $\bar{l}$  mm (var l) 5.35 (1.086),  $\bar{th}$  mm (var th) 2.51 (0.327),  $r = 0.975$ ;  $n = 8$ ); lateral margins of both valves strongly rounded, anterior margins gently rounded, with variably-developed, narrow, rectangular uniplication with an average maximum width of 2.8 mm in 3 adult specimens (range 2.6–3.0 mm); external shell surfaces with strong, closely and regularly spaced concentric ornamentation bearing dense radial and concentric arrays of hollow, erect to prone, fine and coarse spines branching dichotomously anteriorly, with maximum lengths and diameters of 0.6 mm and 50  $\mu$ m and 2.0 mm and 200  $\mu$ m, respectively, fine spines inserted when separation between larger spines exceeds 0.4 mm; ventral interarea triangular, strongly curved, anacline, delthyrium open, dorsal interarea narrow, slightly curved, anacline, with open notothyrium.

Ventral interior with small, flattened teeth supported by receding, convergent, dental plates forming lateral margins of elevated, tongue-shaped spondylium averaging 62% as wide as long ( $\bar{l}_{sp}$  mm (var  $l_{sp}$ ) 2.13 (0.025),  $\bar{w}_{sp}$  mm (var  $w_{sp}$ ) 1.31 (0.018),  $r = 0.930$ ;  $n = 7$ ), spondylium supported by strong, thickened, median ridge and flanked laterally by low, flattened, bosses of shell separating two pairs of narrow canals, up to 0.4 mm wide, of digitate mantle canal system.

Dorsal interior with short, curved, thickened, triangular brachiophores flanked by elongate, narrow, shallow sockets, brachiophores supported by short, divergent brachiophore bases sloping sharply down to valve floor to form lateral margins of broadly triangular, sessile, notothyrial platform averaging 65% as long as wide (range 59–67%;  $n = 5$ ); floor of valve with two discrete pairs of elevated adductor muscle scars, with a narrow elongate, anteriorly divergent, pair averaging 36% as wide as long ( $\bar{l}_{sc}$  mm (var  $l_{sc}$ ) 1.18 (0.064),  $\bar{w}_{sc}$  mm (var  $w_{sc}$ ) 0.42 (0.004),  $r = 0.845$ ;  $n = 9$ ) situated posterolaterally, and a broad, spatulate, subparallel pair symmetrically disposed on either side of short, low, median ridge and averaging 62% as wide as long ( $\bar{l}_{sc}$  mm (var  $l_{sc}$ ) 1.31 (0.066),  $\bar{w}_{sc}$  mm (var  $w_{sc}$ ) 0.81 (0.014),  $r = 0.787$ ;  $n = 9$ ), three pairs of narrow canals, 0.7 mm wide posteriorly tapering to 0.2 mm anteriorly, of digitate mantle canal system radiating anteriorly from between, and laterally of, muscle scars.

**LECTOTYPE.** Natural external and internal moulds of incomplete brachial valve. Sedgwick Museum, Cambridge, reg. no. A10379a, b (Fig. 191a, b). Sel. Cocks 1978: 136; fig'd Reed in Gardiner & Reynolds 1909: pl. 6, figs 14a, b. From coarse ash near Shangort, Tourmakeady, Co. Mayo. Fig. 191.





**Figs 191–198** *Acanthoglypha affinis* (Reed). Fig. 191a, b, lectotype (sel. Cocks 1978: 136) SMA10379a, b, external natural mould of incomplete brachial valve (a) and its corresponding internal mould (b), both  $\times 5$ ; from coarse ash near Shangort, Tourmakeady. Fig. 192, BB 95579, interior of incomplete brachial valve,  $\times 4$ ; Fig. 193, BB 95577, interior of pedicle valve,  $\times 5$ ; Fig. 194a, b, BB 95575, interior and anterior views of pedicle valve, both  $\times 5$ ; Fig. 195a, b, BB 95576, exterior and anterior of brachial valve: a,  $\times 4$ ; b,  $\times 5$ ; Fig. 196a, b, c, BB 95574, exterior, anterior and interior views of brachial valve, all  $\times 4$ ; Fig. 197, BB 95578, interior of incomplete brachial valve,  $\times 4$ ; Fig. 198a, b, BB 95580, branching spines on fragment: a,  $\times 14$ ; b,  $\times 32$ .

FIGURED MATERIAL.		length	width (mm)
Pedicle valve; BB 95575		5.5	8.0
Pedicle valve; BB 95577		5.3	8.4
Brachial valve; BB 95574		5.2	11.6
Brachial valve; BB 95576		4.8	8.6
Incomplete brachial valve; BB 95578		—	—
Incomplete brachial valve; BB 95579		7.1	—
Fragment; BB 95580		—	—

All Loc. 1.

DISCUSSION. In 1909 Reed described a new species, *Streptis affinis*, in an appendix to the account of the geology of the Tourmakeady district by Gardiner & Reynolds. The species was founded on the natural external and internal moulds of an almost complete brachial valve (not a pedicle valve as stated by Reed), and several small fragments of shell, collected from a coarse ash. These moulds, constituting the lectotype of the species, the genotype of *Acanthoglypha*, were subsequently presented to the Sedgewick Museum, Cambridge, by Gardiner. They are illustrated herein (Fig. 191a, b) along with representative etched specimens of *Acanthoglypha affinis* from the Tourmakeady Limestone, with which they are conspecific. Reed's assignment of his specimens to the triplesiacean genus *Streptis* is somewhat surprising, even allowing for his misinterpretation of the lectotype as a pedicle valve, because the shell possesses none of the characters diagnostic of this superfamily.

*A. affinis* (Reed) is at present the sole known representative of the new genus.

#### Genus *SYNTROPHINA* Ulrich in Weller & St Clair, 1928

##### *Syntrophina magna* sp. nov.

Figs 199–203

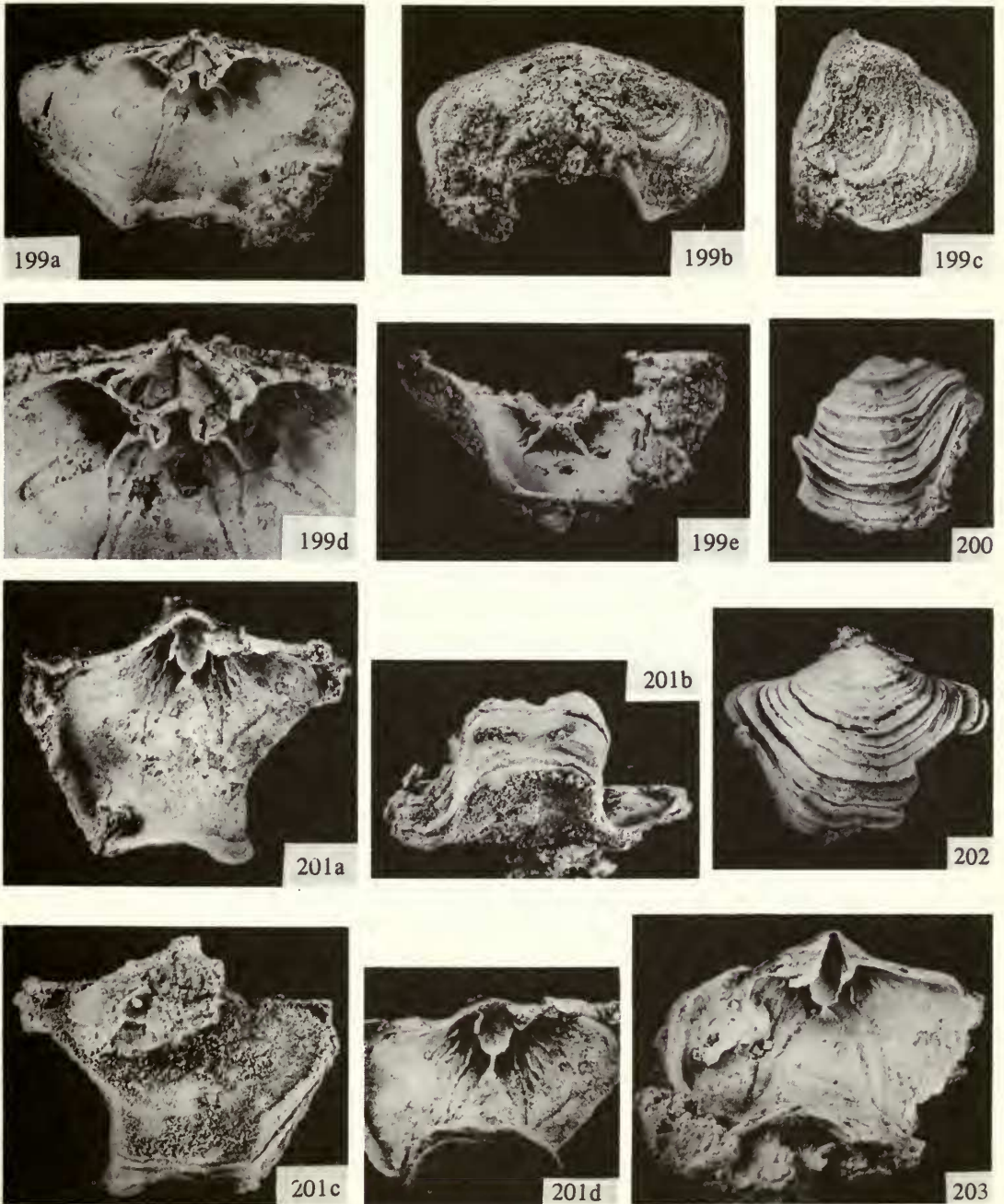
DIAGNOSIS. Large, broadly semi-elliptical *Syntrophina*; pedicle valve moderately convex averaging 76% as long as wide and 43% as deep as long; brachial valve moderately to strongly convex averaging 71% as long as wide and 56% as deep as long; external shell surfaces ornamented by regularly-spaced concentric lamellae with an average spacing of 0.7 mm.

NAME. 'Large'.

DESCRIPTION. Large, broadly semi-elliptical, strong uniplicate *Syntrophina*; pedicle valve moderately convex, averaging 76% as long as wide ( $\bar{l}$  mm (var l) 12.40 (4.33),  $\bar{w}$  mm (var w) 16.30 (8.43),  $r = 0.989$ ;  $n = 7$ ) and 43% as deep as long ( $\bar{l}$  mm (var l) 12.32 (4.38),  $\bar{th}$  mm (var th) 5.33 (1.29),  $r = 0.942$ ;  $n = 6$ ); brachial valve moderately to strongly convex, averaging 71% as long as wide (range 62–76%;  $n = 3$ ) and 56% as deep as long (range 50–64%;  $n = 3$ ); lateral margins of both valves gently rounded, becoming moderately geniculate in adult growth stages, anterior margins of both valves gently rounded or truncated, with strong rectangular, geniculate, ventral sulcus attaining a maximum width averaging 48% (range 44–53%;  $n = 4$ ) of valve width; external shell surfaces ornamented by closely spaced concentric lamellae with an average spacing of 0.72 mm (range 0.4–1.0 mm;  $n = 16$ ) and 0.71 mm (range 0.5–1.0 mm;  $n = 12$ ) in two adult valves; ventral interarea narrow, curved, apsacline, dorsal interarea very narrow, gently curved, anacline.

Ventral interior with short, thickened teeth supported by well-developed convergent dental plates contiguous with margins of prominent, elongate, spatulate spondylium averaging 46% as wide as long (range 41–50%;  $n = 3$ ), sessile posteriorly but strongly elevated anteriorly and anterolaterally and supported medially by short, narrow, ridge not extending anteriorly beyond margin of spondylium, median ridge flanked by at least two pairs of short, low ridges radiating posterolaterally from beneath spondylium; floor of valve with well-developed digitate mantle canal system with short trunks of *vascula genitalia*





**Figs 199–203** *Syntrophina magna* sp. nov. Fig. 199a, b, c, d, e, **holotype** BB 95553, brachial valve: a, interior,  $\times 3$ ; b, exterior,  $\times 3$ ; c, lateral view,  $\times 3$ ; d, dorsal cardinalia,  $\times 5$ ; e, anterior view,  $\times 3$ ; Fig. 200, paratype BB 95559, exterior of incomplete pedicle valve,  $\times 3$ ; Fig. 201a, b, c, d, paratype BB 95554, incomplete pedicle valve: a, interior view,  $\times 2$ ; b, anterior view,  $\times 2$ ; c, exterior view,  $\times 2$ ; d, oblique external view,  $\times 2$ ; Fig. 202, paratype BB 95557, exterior of pedicle valve,  $\times 2$ ; Fig. 203, paratype BB 95555, interior of pedicle valve,  $\times 3$ .



impressed posterolaterally and pair of long, narrow, subparallel canals, up to 0.5 mm wide, of *vascula media* extending almost to anterior margin of valve.

Dorsal interior with short, thickened, flattened brachiophores flanked by broad sockets defined by gently concave fulcral plates; brachiophores supported dorsally by gently curved brachiophore bases extending anteriorly beneath brachiophores as rounded lobes curving in towards median axis of valve; brachiophore bases contiguous with triangular notothyrial platform with dimensions of 2.1 × 2.0 mm and 1.7 × 1.5 mm in two specimens, strongly elevated above valve floor and supported by pair of short, divergent, narrow ridges; floor of valve with two pairs of narrow trunks of equidistributed digitate mantle canal system, up to 0.5 mm wide, radiating anterolaterally from beneath dorsal cardinalia.

HOLOTYPE. Brachial valve; BB 95553; length 11.8 mm, width 18.3 mm. Fig. 199.

PARATYPES.		length	width (mm)
	Pedicle valve; BB 95554	14.7	19.0
	Pedicle valve; BB 95555	12.6	17.3
	Pedicle valve; BB 95557	12.8	17.2
	Incomplete pedicle valve; BB 95559	—	—
	Incomplete brachial valve; BB 95556	8.4	—
	Incomplete brachial valve; BB 95558	—	—

TYPE HORIZON AND LOCALITY. Loc. 1.

DISCUSSION. The distinctive paired dorsal septa, combined with the presence of a ventral spondylium simplex and characteristic external ornamentation, confirms that the Tourmakeady specimens are representatives of the clarkellid genus *Syntrophina*. Among described species of this genus, the Irish material most strongly resembles *Syntrophina nana* Ulrich & Cooper (1938: 223) from the Lower Ordovician of Colorado and Nevada. However, the latter species differs in being smaller, and in having a sharply folded sulcus rather than the broadly rectangular sulcus characteristic of the new Irish species.

*Syntrophina magna* is the largest brachiopod in the Tourmakeady fauna, and indeed these specimens are amongst the largest ever assigned to this genus.

### Family PORAMBONITIDAE Davidson, 1853

#### Genus PORAMBONITES Pander, 1830

#### *Porambonites dubius* sp. nov.

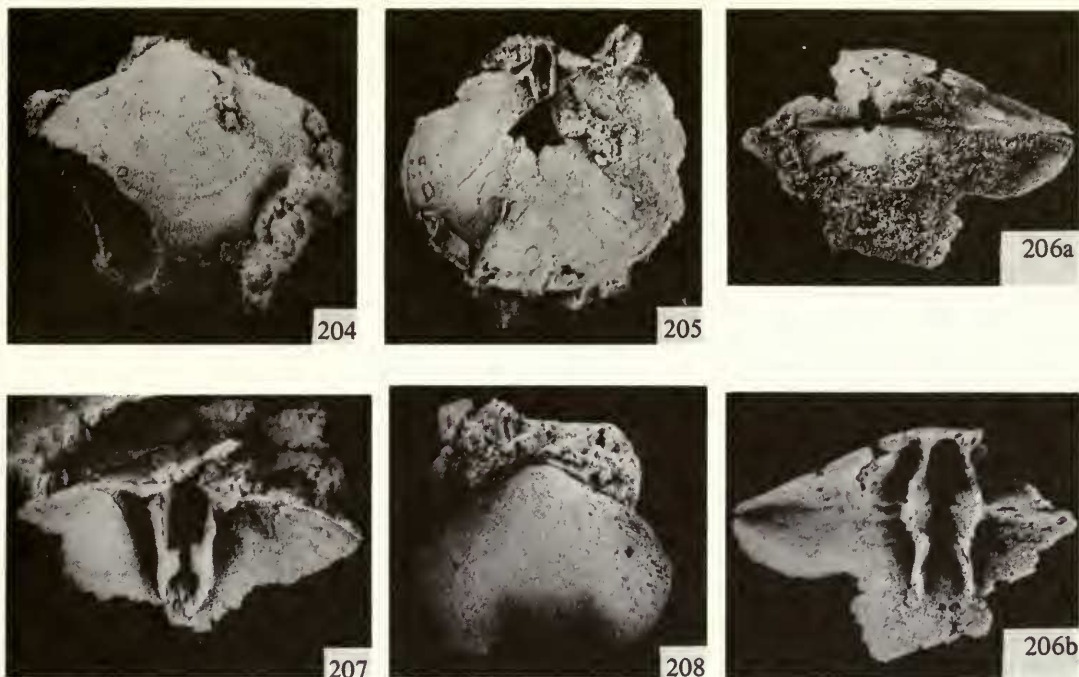
Figs 204–208

DIAGNOSIS. Medium-sized, elongately semi-elliptical to subtriangular *Porambonites*; pedicle valve moderately convex, averaging 83% as long as wide and 30% as deep as long; brachial valve moderately convex, averaging 82% as long as wide and 27% as deep as long.

NAME. 'Problematical'.

DESCRIPTION. Medium-sized, elongately semi-elliptical to subtriangular *Porambonites*; pedicle valve moderately convex, averaging 83% as long as wide (range 79–91%; n = 3) and 30% as deep as long (range 27–32%; n = 3), with a broad rectangular sulcus developed anteromedially; brachial valve moderately convex, 78% and 85% as long as wide and 24% and 29% as deep as long in two specimens, lateral margins of both valves strongly and smoothly rounded, anterior margin smoothly rounded with prominent, broad, median uniplication; external shell surfaces with faint, fine, pitted, radial ornamentation; ventral interarea short, very narrow, gently curved, aplanate, delthyrium open; dorsal interarea short, very narrow, anaplanate, notothyrium open.

Ventral interior with short, small, triangular teeth supported by well-developed dental



**Figs 204–208** *Porambonites dubius* sp. nov. Fig. 204, holotype BB 95560, ventral view of conjoined valves,  $\times 3$ ; Fig. 205, paratype BB 95561, interior of incomplete pedicle valve,  $\times 3$ ; Fig. 206a, b, paratype BB 95562, posterior and anterior views of incomplete conjoined valves, both  $\times 4$ ; Fig. 207, paratype BB 95565, interior of incomplete pedicle valve,  $\times 3$ ; Fig. 208, paratype BB 95563, exterior of incomplete pedicle valve,  $\times 2$ .

plates, parallel posteriorly but converging slightly anteriorly, inner flanks of dental plates thickened anteriorly to form paired, rectangular, subparallel bosses of shell.

Dorsal interior with short brachiophores flanked by small, shallow, sockets and supported by strong, parallel brachiophore bases becoming convergent anteriorly.

**HOLOTYPE.** Conjoined valves; BB 95560a, b; length 13.8 mm, width 15.1 mm. Fig. 204.

**PARATYPES.** Incomplete conjoined valves, BB 95562a, b, 95564a, b; incomplete pedicle valves, BB 95561, 95563 (width 15.4 mm), 95565.

**TYPE HORIZON AND LOCALITY.** Loc. 1.

**DISCUSSION.** *Porambonites* is a problematical taxon, the genus having been subject to considerable subdivision, usually without formal status, in an attempt to justify the inclusion of species displaying great morphological variability. In other brachiopod groups such variability has led to the erection of a number of genera, but the poor preservation and incomplete nature of much of the material on which the *Porambonites* species have been based militate against such taxonomic recognition. In as much as the present Tourmakeady specimens are characterized by a faintly pitted external ornamentation and by long, parallel, dental plates and brachiophore bases, they display the chief morphological characters of the genus *Porambonites*, to which they are accordingly assigned.

The Irish species can readily be distinguished from the majority of previously-published species of *Porambonites* by its unusually fine external ornamentation. *Porambonites?* sp. 2 from the Middle Ordovician of Newfoundland (Cooper 1956: 610; now assigned to a new



genus *Cuparius* Ross, 1971) has a similar ornamentation, but differs from the Irish specimens both in outline (being subhexagonal with the maximum width anteriorly) and in the early, posterior, initiation of a sulcus which is only developed in the anterior portions of the Irish shells. *P. reticulatus* (Pander), from the Middle Ordovician of Russia, differs from the Irish species in outline, in having stronger ornamentation and deeper, wider, sulcation, and in being much more strongly biconvex in lateral profile.

Internally, illustrated specimens of *Cuparius*, including the Newfoundland specimens, have a well-defined, sessile spondylium, a feature lacking in the Irish specimens. Furthermore, *P. dubius* has much stronger brachiophore bases than *C. cardilatus* Ross (1971: 125), the type species of *Cuparius* from the Middle Ordovician of Nevada. On balance, therefore, the Irish material, although largely fragmentary, is sufficiently distinct and abundant to warrant specific recognition.

Family CAMERELLIDAE Hall & Clarke, 1894

Subfamily CAMERELLINAE Hall & Clarke, 1894

Genus *IDIOSTROPHIA* Ulrich & Cooper, 1936

*Idiostrophia costata* Ulrich & Cooper

Figs 209–214

DIAGNOSIS. Medium-sized, transversely to elongately subtriangular *Idiostrophia*, conjoined valves averaging 97% as long as wide and 58% as deep as long, external shell surfaces coarsely costellate with 7–12 angular ribs anteriorly.

DESCRIPTION. Medium-sized, transversely to elongately subtriangular *Idiostrophia*, conjoined valves averaging 97% as long as wide ( $\bar{l}$  mm (var l) 6.33 (2.50),  $\bar{w}$  mm (var w) 6.54 (2.98),  $r = 0.761$ ;  $n = 42$ ) and 58% as deep as long ( $\bar{l}$  mm (var l) 6.49 (2.37),  $\bar{th}$  mm (var th) 3.75 (1.11),  $r = 0.818$ ;  $n = 37$ ), lateral margins of both valves planar, tapering posteriorly, strongly compressed to form flattened, geniculate area posterolaterally, anterior margin moderately to slightly curved, rectimarginate; external shell surfaces with coarsely costellate ornamentation developed anteriorly with 7, 8, 10 and 12 angular ribs on 1, 7, 6 and 1 adult shells respectively.

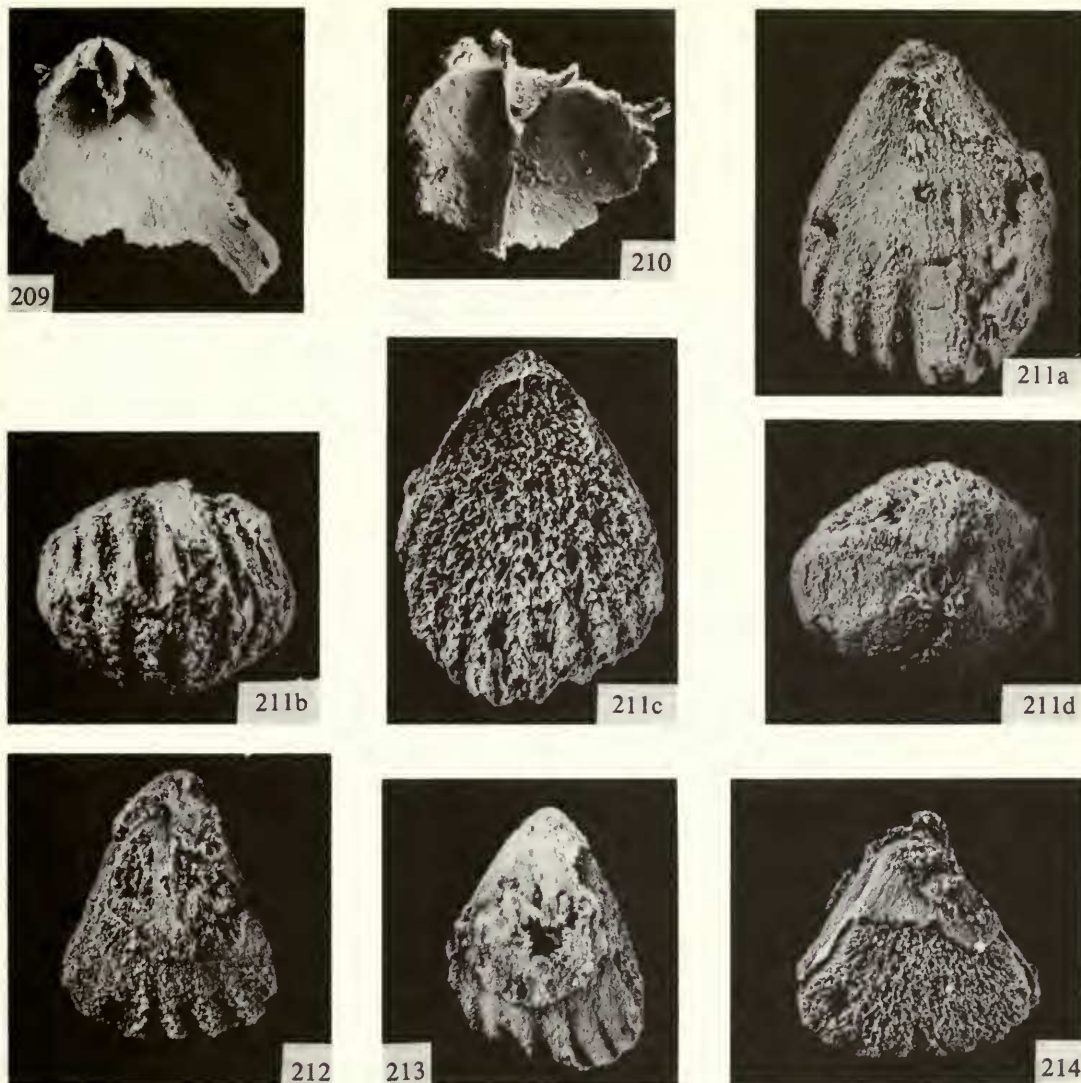
Ventral interior with small, triangular teeth supported by well-developed dental plates converging medially and uniting to form tongue-shaped, strongly elevated, concave spondylium supported by short, thin, tall, median ridge.

Dorsal interior with strong brachiophore bases united medially with long, low, median septum.

		length	width (mm)
FIGURED MATERIAL.	Conjoined valves; BB 95566a, b	9.6	7.2
	Conjoined valves; BB 95567a, b	6.6	6.7
	Conjoined valves; BB 95568a, b	6.6	5.7
	Conjoined valves; BB 95569a, b	7.3	5.9
	Conjoined valves; BB 95571a, b	5.0	5.0
	Incomplete pedicle valve; BB 95570	–	–
	Incomplete brachial valve; BB 95572	–	–
	Incomplete brachial valve; BB 95573	–	–

All Loc. 1.

DISCUSSION. *Idiostrophia* is a thin-shelled genus, and none of the Tourmakeady representatives is preserved whole. Indeed the bulk of the available sample consists of internal casts of conjoined valves from which most of the original shell material has been removed. However, a few fragments show characteristic camerellin internal morphology, and the casts have the flattened margins posterolaterally and triangular shape diagnostic of the genus *Idiostrophia*.



**Figs 209–214** *Idiostrophia costata* Ulrich & Cooper. Fig. 209, BB 95570, interior of incomplete pedicle valve,  $\times 5$ ; Fig. 210, BB 95573, interior of incomplete brachial valve,  $\times 11$ ; Fig. 211a, b, c, d, BB 95566, conjoined valves: a, dorsal view,  $\times 5$ ; b, anterior view,  $\times 5$ ; c, ventral view,  $\times 5$ ; d, posterior view,  $\times 5$ ; Fig. 212, BB 95569, conjoined valves,  $\times 5$ ; Fig. 213, BB 95568, conjoined valves,  $\times 5$ ; Fig. 214, BB 95567, conjoined valves,  $\times 5$ .

*Idiostrophia* is known predominantly from conjoined valves, and few authors have been able to figure the internal morphology adequately. Consequently, much of the taxonomic differentiation at the species level has depended upon shell shape and ribbing. However, Ross (1972: 23) sounded a salutary warning about the use of such criteria when he described from a single piece of limestone over 500 conjoined valves which displayed extremely variable shape and rib-counts. In effect, the sample yielded a complete gradation between a range of morphological features which, taken in isolation, would have defined at least 4 separate taxa. The shape of the Tourmakeady specimens is also very variable, with 40% of the conjoined valves being longer than wide, and the remainder wider than long. Such ratio



variation, however, does not constitute valid grounds for subdividing the sample as the two variants are present throughout the size range of the sample. Statistical tests have, in addition, shown that such variability is not allometric. The number of ribs does, however, remain relatively constant throughout the sample. *I. costata* from the Lower Ordovician Mystic Conglomerate of Quebec (Ulrich & Cooper 1938: 250) has a similar rib count, and also resembles the Irish specimens in size and shape. The Irish specimens are consequently considered to be conspecific, at least until a comparison of internal morphology can be made.

### Acknowledgements

A number of our colleagues kindly provided assistance during the course of this study, either by allowing us access to collections under their care, or by examining and commenting upon otherwise inaccessible specimens on our behalf. In this respect we should particularly like to thank Dr G. A. Cooper of the U.S. National Museum, Dr L. R. M. Cocks of the British Museum (Natural History), Professor A. J. Rowell of the University of Kansas, and Dr M. R. Bassett, Welsh National Museum. The work was funded by NERC Grant GR3/3934, which is gratefully acknowledged.

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